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June 1973

DCPA ATTACK ENVIRONMENT MANUAL

CHAPTER 2

WHAT THE PLANNER NEEDS TO KNOW ABOUT BLAST AND SHOCK

DEFENSE CIVIL PREPAREDNESS AGENCY
DEPARTMENT OF DEFENSE

JUNE 1973

DCPA ATTACK ENVIRONMENT MANUAL

WHAT THE EMERGENCY PLANNER NEEDS TO KNOW ABOUT THE NATURE OF NUCLEAR WAR

No one has gone through a nuclear war. This means there aren't any natural experts. But civil defense officials are in the business of preparing against the possibility of nuclear war. Intelligent preparations should be based on a good understanding of the operating conditions that may occur in a war that has never occurred. Lacking such understanding, emergency operating plans probably won't make much sense if they have to be used.

This manual has been prepared to help the emergency planner understand what the next war may be like. It contains information gathered from two decades of study of the effects of nuclear weapons and the feasibility of civil defense actions, numerous operational studies and exercises, nuclear test experience, and limited experience in wartime and peacetime disasters that approximate some of the operating situations that may be experienced in a nuclear attack. In short, it summarizes what the Defense Civil Preparedness Agency now knows about the nuclear attack environment as it may affect operational readiness at the local level.

LIST OF CHAPTER TITLES

PREFACE TO CHAPTER 2

This description of the blast and shock effects of nuclear attack is intended to provide the operational planner with the basic information needed to plan realistic actions to be taken in damaged areas. It does not assume knowledge of the material in subsequent chapters of the Manual. It does presume that the reader is familiar with the material in Chapter 1—Introduction to Nuclear Emergency Operations.

Information is presented in the form of "panels" each consisting of a page of text and an associated sketch, photograph, chart or other visual image. Each panel covers a topic. This preface is like a panel with the list of topics in Chapter 2 shown opposite. If the graphic portion is converted into slides or vugraphs, the chapter or any part can be used in an illustrated lecture or briefing, should that be desired.

The ordering of topics begins with three introductory panels, followed by three panels on air blast characteristics. There are five panels on basic blast effects, followed by seven on survival in various types of buildings. Three subsequent panels summarize the best available blast shelter and how best to use it. The next nine panels discuss blast damage to equipment and facilities, including the nature of the resulting debris situation. Two panels provide answers to common questions about the effects of terrain and builtup areas on blast destruction. Finally, four panels summarize the overall blast effects in urban areas. There is a list of suggested additional reading for those who are interested in further information on the general subject.

CONTENTS OF CHAPTER 2

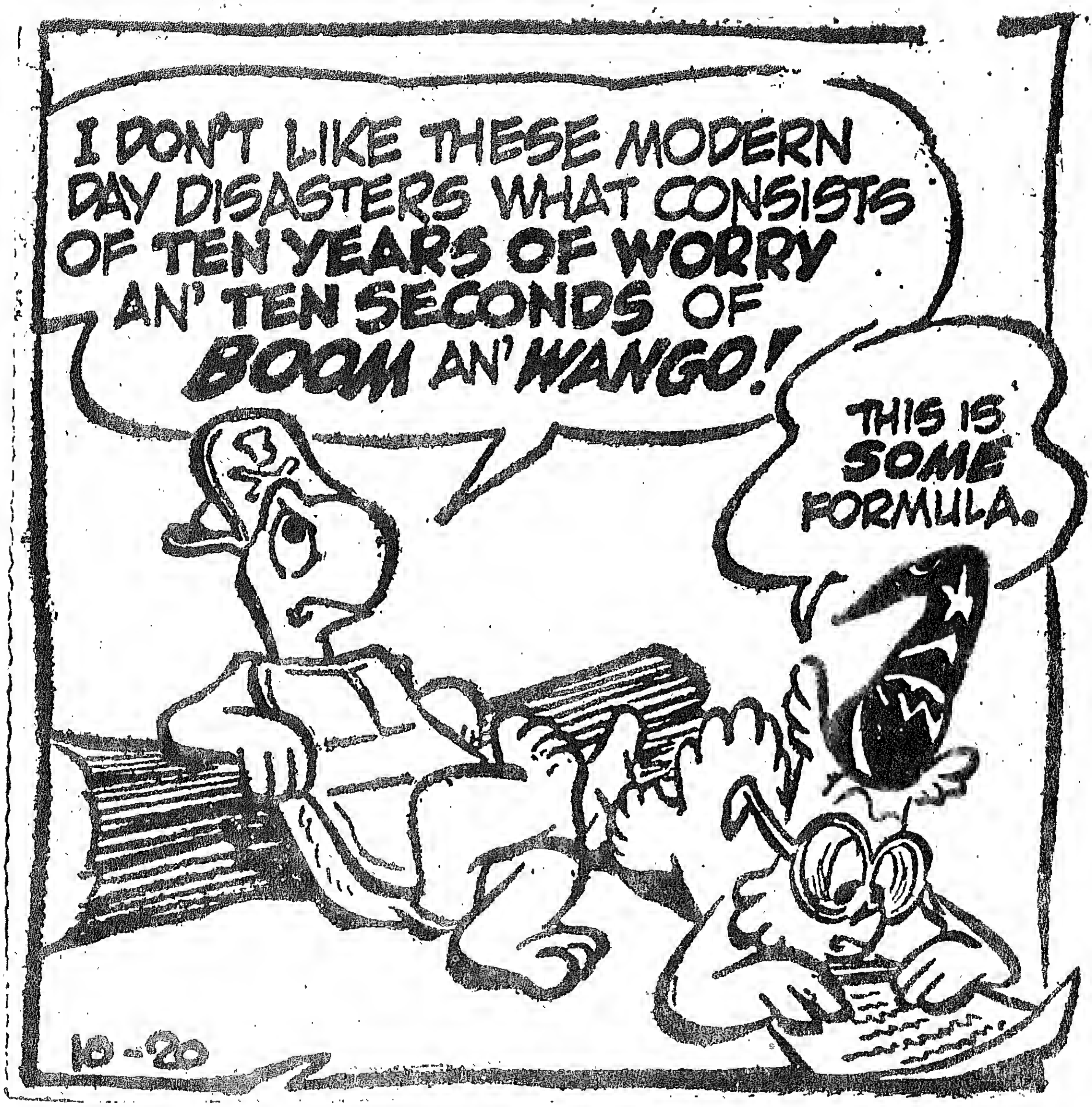
"WHAT THE PLANNER NEEDS TO KNOW ABOUT BLAST AND SHOCK"

GENERAL EFFECTS OF BLAST

The blast or shock wave created by an exploding nuclear weapon is responsible for the "boom and wango" part of nuclear attack. This Walt Kelly character, Churchy La Femme, doesn't have the timing quite right. The "worry" has lasted more than 10 years and the blast wave is capable of causing damage for more than 10 seconds after the detonation.

At one minute following the detonation of a 5-MT surface burst, the blast wave has traveled outward to about 15 miles from ground zero. Its pressure above the normal pressure of the atmosphere (overpressure) has decreased to about eight-tenths of a pound per square inch (psi) and it is now capable only of window breakage and similar minor damage. Closer in, however, it has left a region of increasing destruction toward ground zero. Buildings are damaged or destroyed, utilities disrupted, and debris hurled into the streets. People with insufficient protection have been killed or injured.

The destructive potential of the blast wave will generate most of the need for repair and rehabilitation following attack. The character of this damage will be described later in this chapter. But, first, we will concentrate on the survival of people, since the most important part of the civil defense mission is the saving of lives.


I DON'T LIKE THESE MODERN DAY DISASTERS WHAT CONSISTS OF TEN YEARS OF WORRY AN' TEN SECONDS OF BOOM AN' WANGO!
THIS IS SOME FORMULA.
10-20

PANEL 1

SURVIVAL IN ORDINARY BUILDINGS

The planner will be concerned primarily with the use of ordinary buildings, such as those identified in the National Fallout Shelter Survey (NFSS) and residences, as shelter for the population. The best available protection should be used to shelter the population in a particular community.

In areas potentially subject to direct effects, more than just fallout protection should govern the selection of "best available shelter space." A first approximation of the relative protection afforded by buildings is shown here. Note that blast survival is always better in basements (belowground) than it is aboveground. In particular, people are expected to survive closer in to the detonation (at a higher overpressure) in home basements than in the aboveground floors of NFSS buildings identified as having adequate fallout shelter. Where home basements exist, they deserve special consideration in the development of community shelter use plans.

An indication of the life-saving potential of intensive use of basements for shelter was referred to in Chapter 1. It will be recalled that a series of attacks on the Detroit urban area was described. For the heaviest attack—fifteen 5-MT ground bursts— somewhat less than 25 percent of the population survived the blast effects. The calculation was based on a median lethal overpressure (MLOP) of 6.5 psi, generally typical of aboveground locations. When the calculation was repeated using a MLOP of 12 psi, the blast survivors increased to 45 percent.

The information shown here is only approximate. Some basements offer no more blast protection than aboveground space. To see why this is so, we need to understand some key characteristics of the blast wave and how it damages buildings and people. We will be concerned with the "low overpressure" region of the blast area, where overpressures do not exceed, say, 20 psi. Closer in to a detonation, the blast characteristics are more complex than described here but they are of primary interest to the designers of blast-resistant structures and not to emergency planners.

BLAST PROTECTION IN CONVENTIONAL BUILDINGS

Location	Median Lethal Overpressure*	
	Residences	NFSS Buildings
Aboveground	5 psi	7 psi
Belowground	10 psi	12 psi

*The median lethal overpressure is that blast overpressure at which 50 percent of the occupants may be expected to be fatally injured.

THE IMPORTANCE OF "LOW" OVERPRESSURES

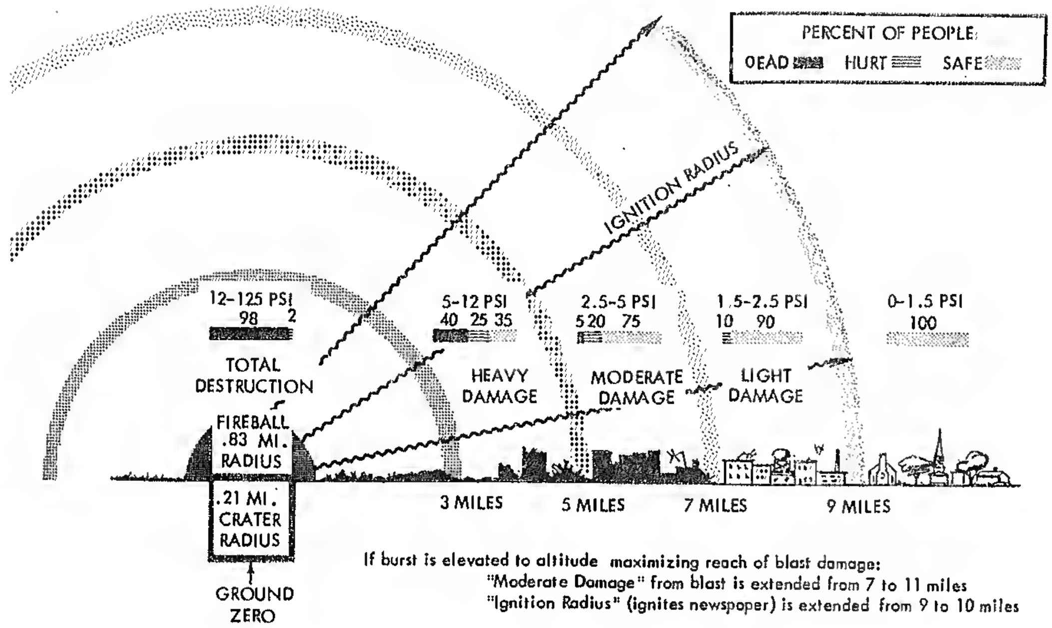
The fact that civil defense planning is largely concerned with the low overpressure region of the direct effects area should not be interpreted as concern for only a small part of the area affected by blast. Quite the contrary, most of the direct effects area is subjected to "low" overpressures. We have seen that an ability to position the population of the Detroit metropolitan area in basements with a median lethal overpressure of 12 psi would have doubled the survivors of a very heavy attack.

The importance of knowledge about the effects of low overpressure is graphically illustrated in these two sketches. The upper sketch is the picture of direct effects of a 5-MT surface burst that has been presented in OCD literature, including the Federal Civil Defense Guide, for the past 5 years. It shows the limit of light damage as extending to 9 miles from ground zero. The lower sketch is the recent revision of this effects picture. It shows light damage extending to 13 miles. This change more than doubles the direct effects area.

A close comparison of the two sketches reveals that the principal change was a downward shift of 1/2 psi in the overpressure needed to cause damage—from 2.5 psi to 2 psi for moderate damage and from 1.5 psi to 1 psi for light damage. The change came about as the result of experimental work, some of which will be described in this chapter. It is significant that such small changes in knowledge of blast effects can make such large changes in the area of coverage. The implication for emergency planning is that small changes in the vulnerability of people can make large changes in survival. Intelligent use of best available shelter can result in such changes.

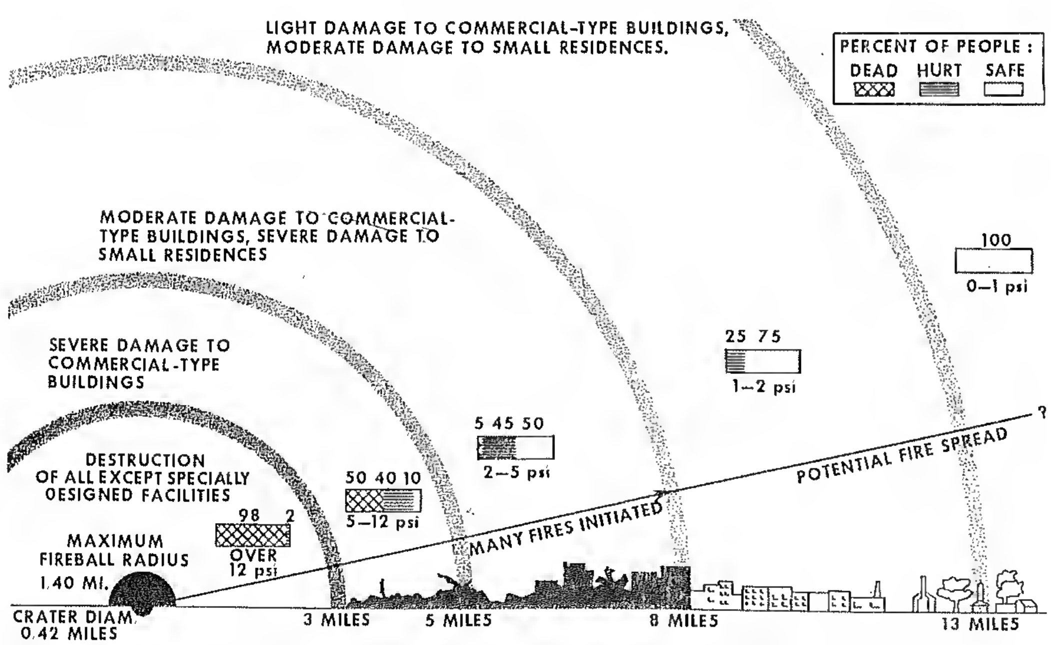
And, remember: The area covered by overpressures less than 12 psi constitutes 95 percent of the whole area experiencing at least 1 psi blast.

EFFECTS OF A 5 MT BLAST



If burst is elevated to altitude maximizing reach of blast damage:
"Moderate Damage" from blast is extended from 7 to 11 miles
"Ignition Radius" (ignites newspaper) is extended from 9 to 10 miles

DIRECT EFFECTS OF 5 MT. BLAST (SURFACE BURST)



IF BURST IS ELEVATEO TO ALTITUOE MAXIMIZING THE REACH OF BLAST OAMAGE, MODERATE DAMAGE FROM BLAST AND INITIAL FIRES ON A CLEAR DAY ARE EXTENDED FROM 8 MILES TO 13 MILES.

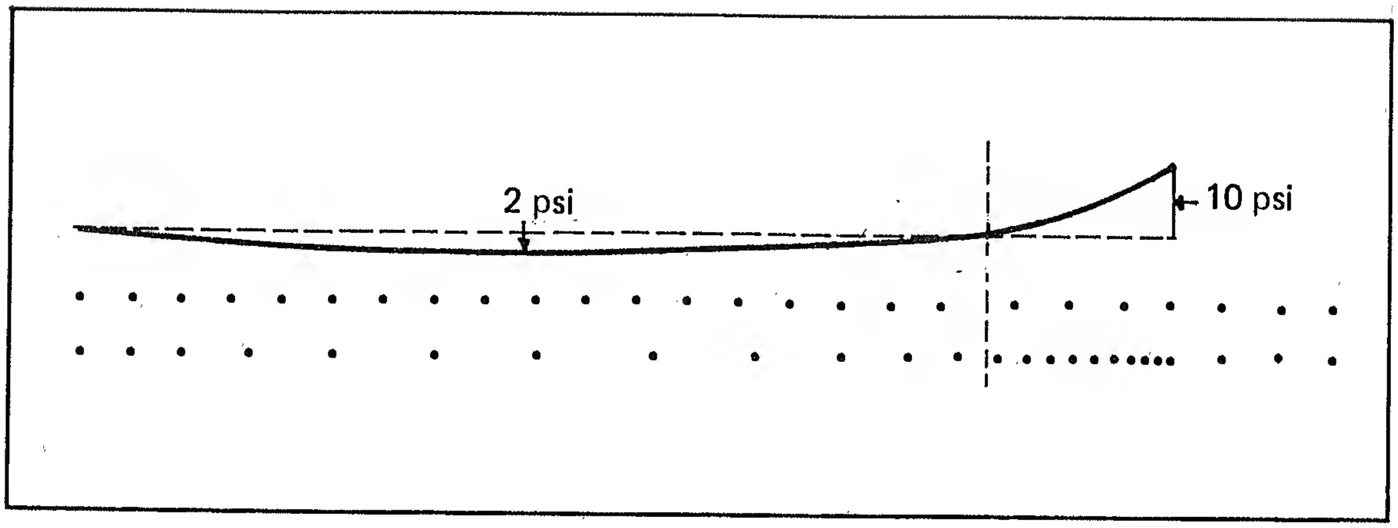
WHAT THE BLAST WAVE IS

When a nuclear weapon explodes in air, the air surrounding the detonation point is rapidly compressed and forced outward, initially at speeds much higher than the speed of sound. A blast or shock wave is created whenever air is suddenly forced to move very rapidly. Commonly observed but very weak shock waves are those created when the end of a whip is snapped to supersonic velocities or when a supersonic jet aircraft creates a "sonic boom."

As the blast wave expands, it encompasses an ever greater volume of space. The peak pressure at the leading edge of the wave (commonly called the shock front) continuously decreases as it expands outward and the speed of expansion slows down. (The amount by which this pressure exceeds normal atmospheric pressure is known as the overpressure.) At great distances from a nuclear detonation, the shock front velocity slows to the speed of sound (about 1100 feet per second or 750 miles per hour). At this point, the shock front disappears and the disturbance becomes an ordinary sound wave—a "boom."

A schematic illustration of the blast wave is shown here. The upper row of dots represents a row of undisturbed air molecules. As undisturbed air is overtaken by the shock front, the air molecules are jammed up into the leading edge of the wave and carried along for a bit, as shown by the lower row of dots. It is this compression of the air in the shock wave that produces the overpressure. The jammed-up air molecules never reach the speed with which the blast wave is expanding and gradually fall behind the shock front. Because of the violent outward movement, however, at some distance behind the wave front, the air becomes thinner than normal and the pressure is less than atmospheric, indicated by the vertical dashed line in the sketch. The overpressure behind the shock front falls off to an "underpressure" about one-fifth the overpressure at the shock front. The air behind the shock front eventually begins to flow back into the low-pressure region to restore the normal atmospheric pressure.

The overpressure part of the blast wave is called the "positive phase;" the underpressure part, the "negative phase." Since the negative phase contributes little to casualties and destruction, the planner need not be concerned with it.

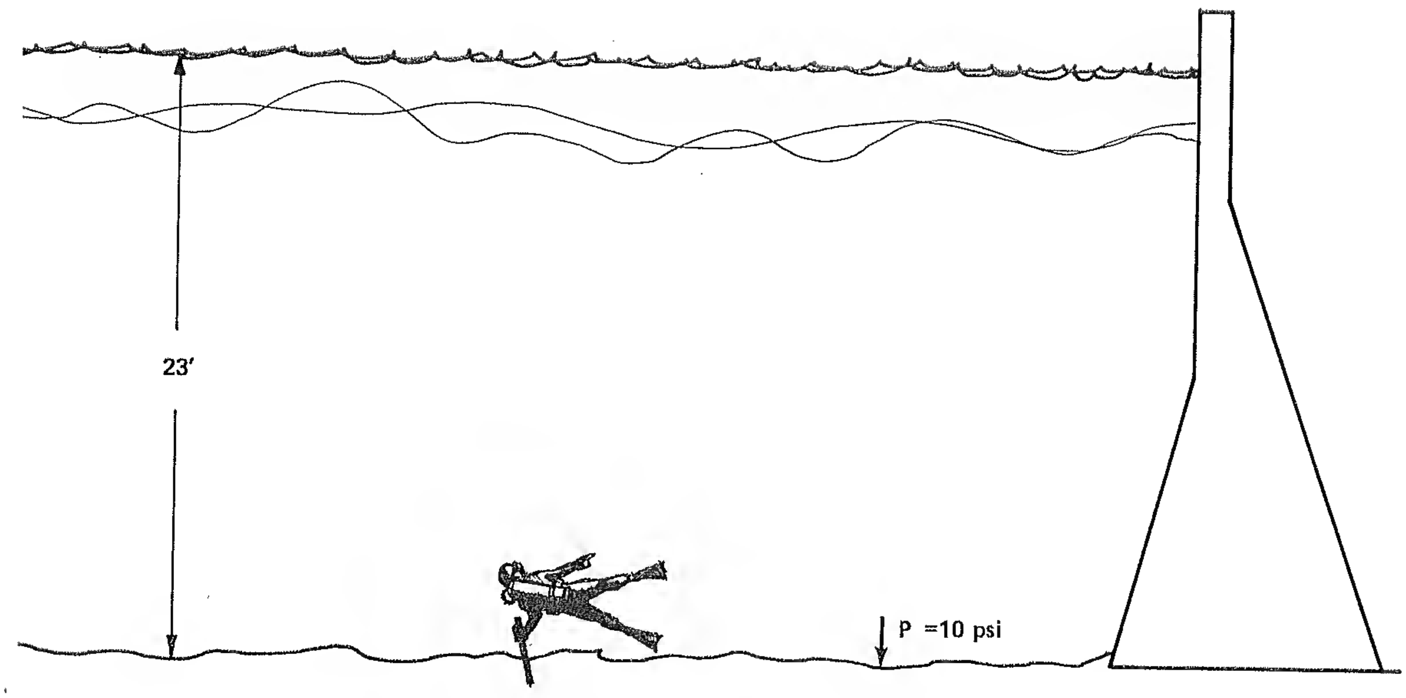


PANEL 4

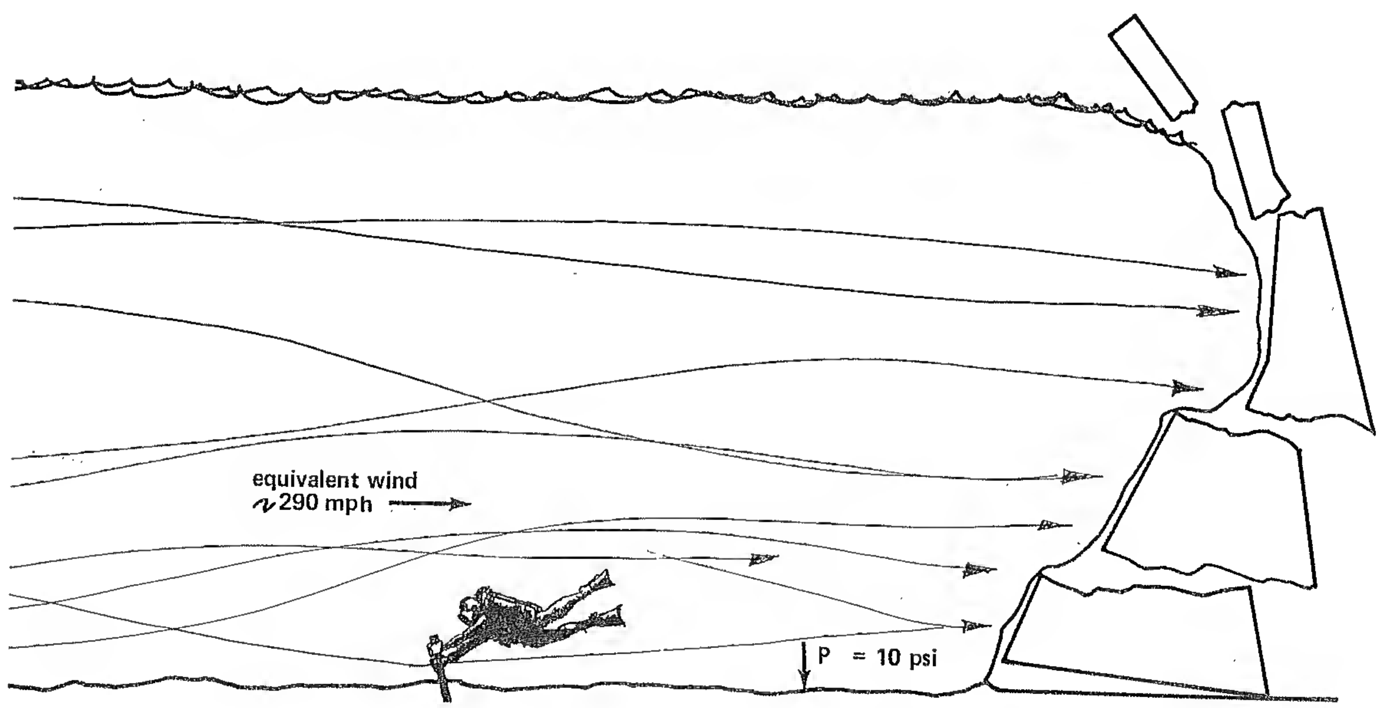
A DAM ANALOGY

People are so accustomed to the world around them that they are not aware that they are being pressed in by the weight of the atmosphere, about 15 pounds per square inch at sea level. Nevertheless, the pressure is real. In the upper picture, we see a diver holding to an anchor at the bottom of a reservoir 23 feet deep. At that depth, the weight of water above him exerts an overpressure of about 10 psi above atmospheric pressure and he would be aware of it.

If the dam were suddenly to fail, as in the lower figure, he remains under the pressure of 23 feet of water but now the water begins to move and tends to tear him from his anchor point. In an air blast wave, this "tearing force" is a wind produced by the outward movement of the air molecules. At an overpressure of 10 psi, the momentary wind velocity accompanying the shock front is about 290 miles an hour.



HYDROSTATIC PRESSURE
BEHIND DAM



HYDROSTATIC PRESSURE + WATER MOVEMENT

PANEL 5

A DAM ANALOGY

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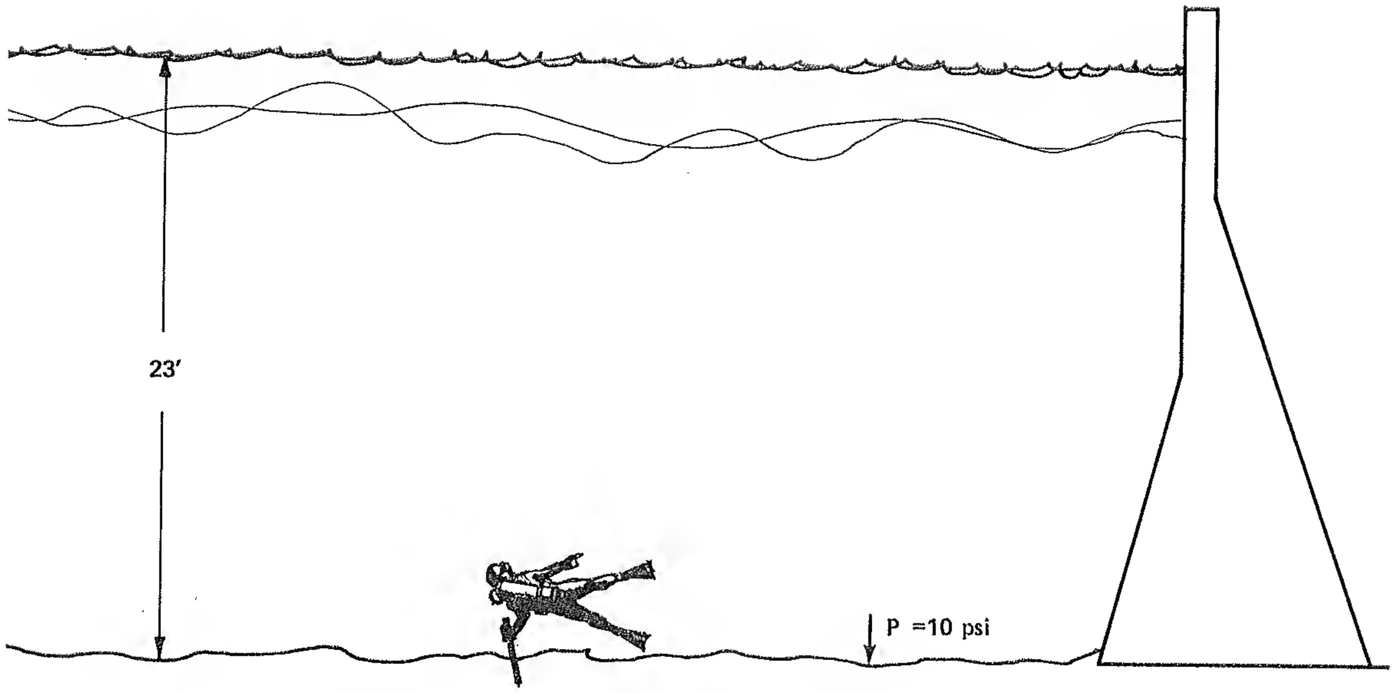
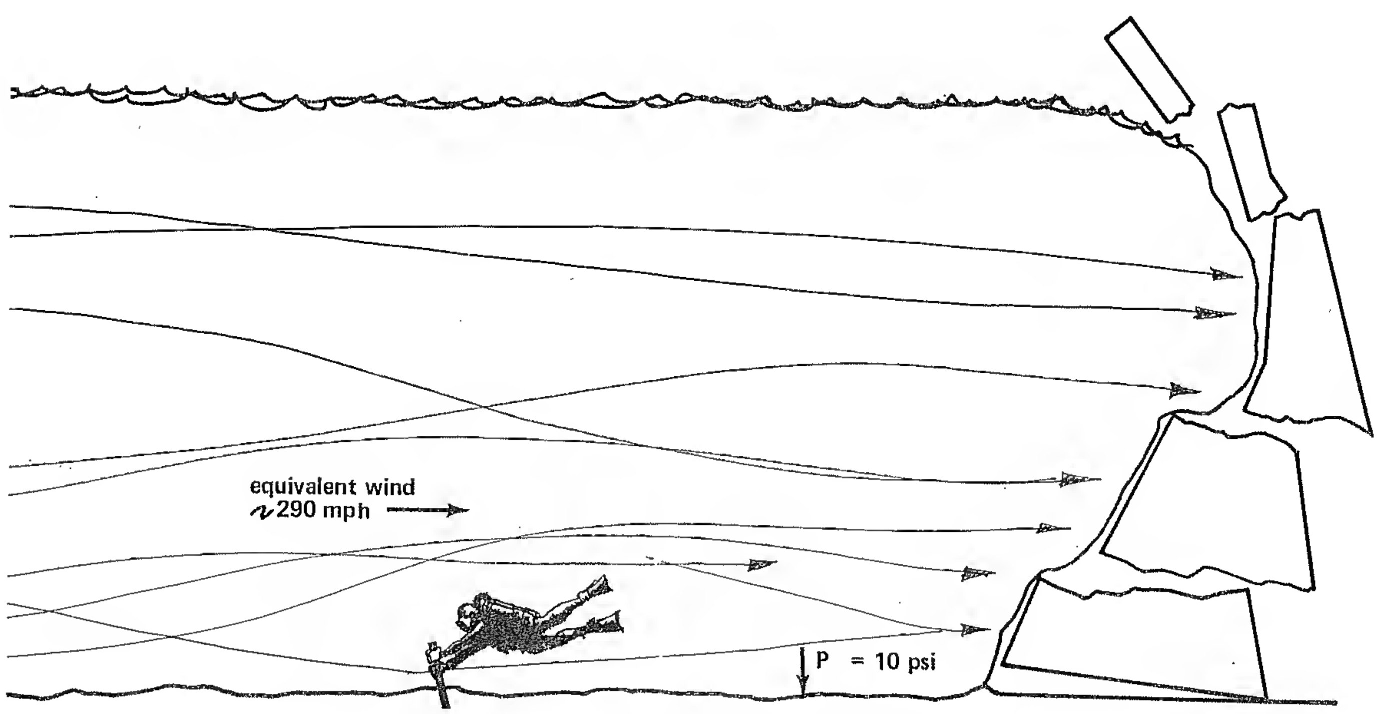


HYDROSTATIC PRESSURE BEHIND DAM



HYDROSTATIC PRESSURE + WATER MOVEMENT

PANEL 5

RELATIONSHIP OF BLAST WIND TO OVERPRESSURE

It will be seen that both the overpressure in the blast wave and the blast wind are important causes of damage and casualties. This table shows the relationship between the two. All buildings will suffer light damage at about 1 psi peak overpressure—shattered windows, doors damaged or blown off the hinges, and interior partitions cracked. The maximum blast wind velocity would be about 35 miles per hour. As the overpressure increases, so does the blast wind, exceeding hurricane velocities above about 2 psi.

The most significant difference between the blast effects of kiloton-yield weapons and megaton-yield weapons is the length of time that the overpressure and blast wind persist. For kiloton-yield detonations, such as those at Hiroshima, Nagasaki, and at the Nevada Test Site, the duration in the low overpressure region is about one second. For detonations in the megaton-yield range, the duration is 5 seconds or more. (Actually, the duration of the positive phase varies as the cube root of the yield; the blast wave for a 20-MT detonation lasts **10 times** as long as that for a 20KT explosion.)

This change in duration is most significant for the blast wind gust. To get an idea of the significance, clap your hands twice, one second apart. Then, using the 1001, 1002 procedure for counting at one second intervals, clap your hands 6 seconds apart. Imagine the sort of winds shown on this chart persisting for several seconds. Of course, as the overpressure behind the shock front falls off, the blast wind lessens accordingly.

BLAST WAVE CHARACTERISTICS
(surface burst)

Peak Overpressure (psi)	Wind Velocity (mph)	Wind Duration for 5-MT Burst (sec)
1	35	9.5
2	70	8.5
5	160	6.8
10	290	6.0
20	470	5.8
30	670	5.6
100	1400	4.3

EFFECTS ON PEOPLE IN THE OPEN

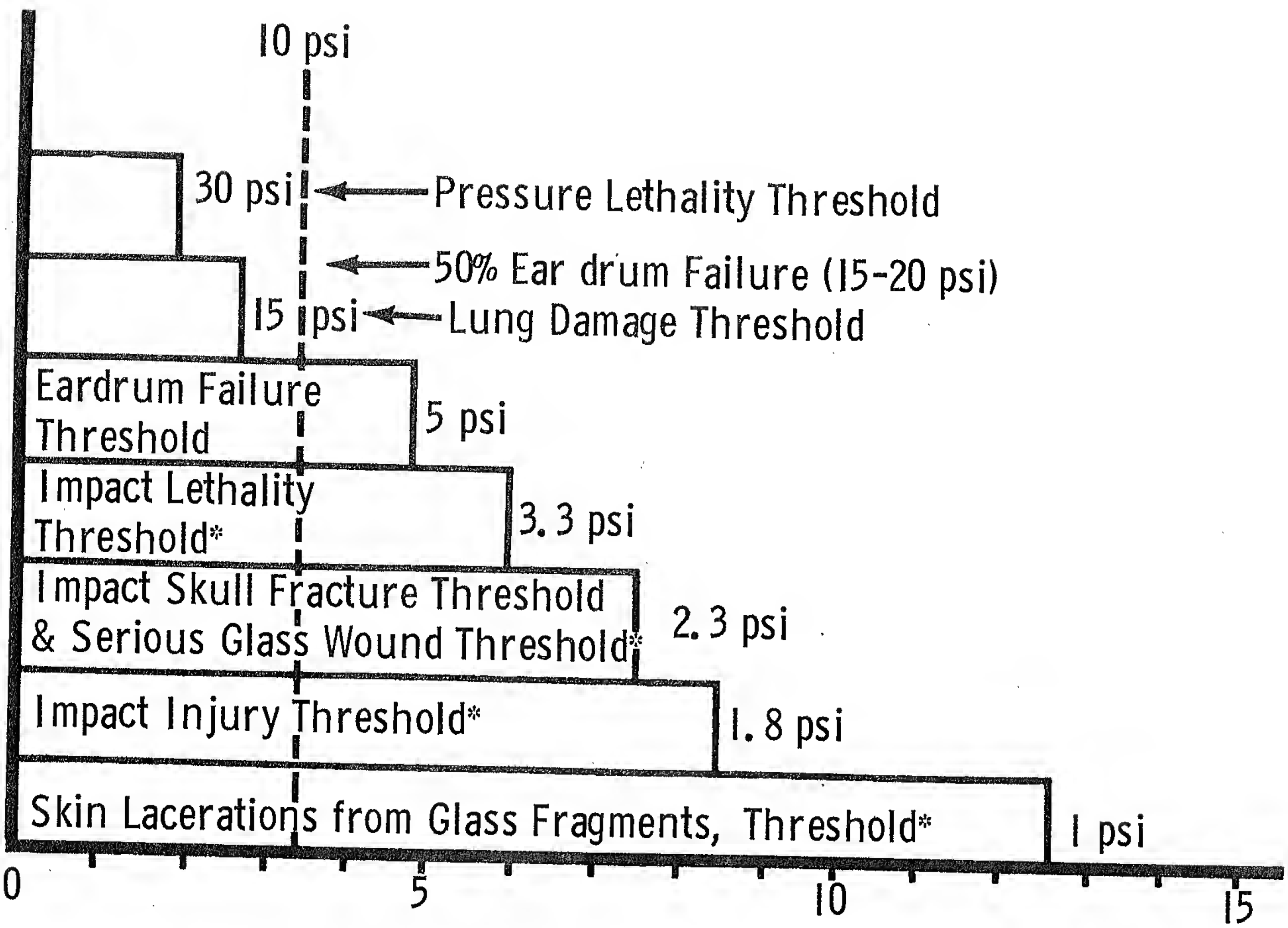
Consider a person standing in the open at a distance of three and one-third miles from the detonation of a 5-MT ground burst. The shock wave would arrive at his location about 7 seconds after the detonation. He would first feel the sharp "air slap" as the shock front strikes. He would be enveloped in less than a thousandth of a second. He would then feel a 10-psi pressure over his body. As can be seen from the chart, this pressure would be too low to cause death or lung damage. He might experience a perforated eardrum although 20 psi would be required to make this likely. Eardrum failure has been recorded, however, at overpressures as low as 5 psi.

In addition to this overpressure, however, the person would experience a blast wind of as high as 290 miles per hour for several seconds. This wind would blow him through the air for a considerable distance. When he struck the ground, he would likely sustain injury and, possibly, a fatal injury. If there were structures nearby, he might also sustain injury from flying fragments of glass or other debris.

The implication of the chart is that it is the bodily displacement and missile hazard created by the blast wind that causes most injury and death, not the overpressure itself. The overpressure, however, can break up buildings, creating the missiles that might cause injury. Very generally, a person outside in a residential area has about the same chance of surviving the blast wave as he would in a frame residence.

The information shown here comprises a small part of the great amount of data that exists from animal experiments and weapons tests for specific injuries and causes of death.

BLAST INJURY THRESHOLDS IN OPEN



Miles from GZ from 5-MT Surface Burst

*For impact injury or death to occur at stated overpressure, the body must be thrown at least 10 feet before impact. Otherwise, a higher overpressure is required to achieve necessary velocity. Glass fragments must also travel at least 10 feet.

Based on The Nature of the Problems Involved in Estimating the Immediate Casualties from Nuclear Explosions, White, C.S. CEX 71.1. NTIS, U.S. Department of Commerce, Springfield, Virginia 22151.

DAMAGE TO BUILDINGS

We have concluded that people are mainly affected by the winds accompanying the blast wave. People are so quickly engulfed by the shock front that there is little time for the overpressure to act on the near side before it is also acting on the far side. Being relatively non-crushable, people react mainly to the wind. There are structures, such as telephone poles, smoke stacks, and radio towers that behave the same way.

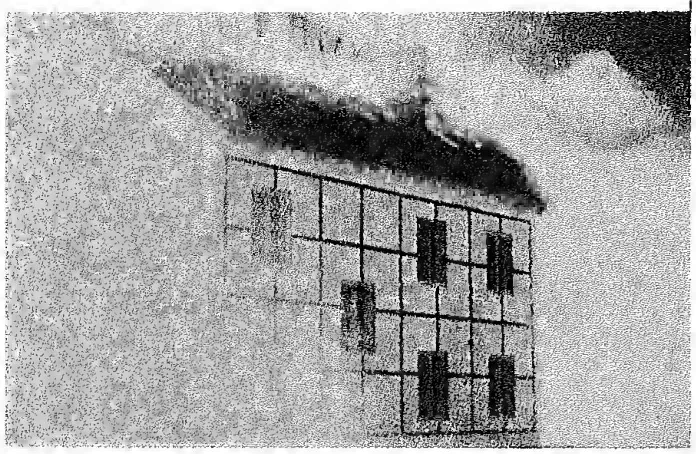
Buildings, however, are large enough that the overpressure acts on the facing side before it can act on the other sides. Buildings are therefore affected by both the overpressure and the blast wind. These views show the effects of blast from a 47-KT weapon on a brick test house, as seen from the rear. In the first picture, the blast front has just struck the far side of the house and is spilling around the structure. The overpressure in the shock front is about 3 psi, but the load on the building face at this time is about doubled because the blast wave is reflected. Damage is occurring to roof panels.

The situation 0.6 of a second later is shown in the second picture. Light roofing panels are being hurled by the blast wind, which had a maximum velocity of about 100 miles per hour. The roof framing is lifted nearly vertically by the wind force. At 1 second after blast wave arrival (third picture), the positive phase is over, the roof rafters have moved back into place and roof panels are falling to the ground.

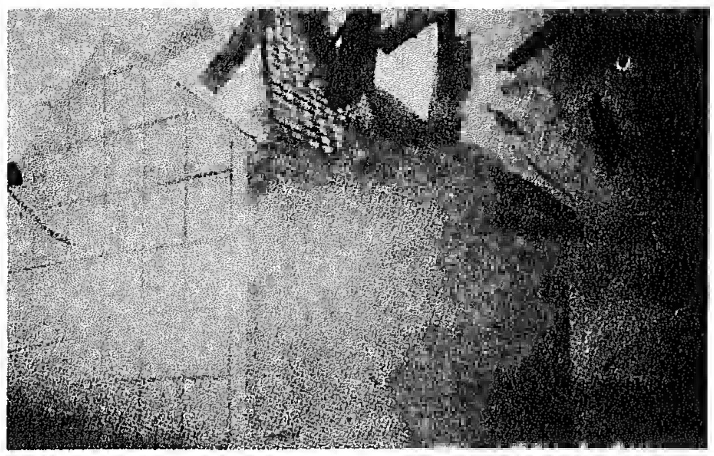
The final picture shows a front view of the house after the test. The roof has collapsed but the main brick structure appears to be in good condition. The test report estimates that this structure suffered 10 percent damage. It should be noted that this test structure represented a kind of masonry construction considerably stronger than ordinary U.S. houses.

Is this test representative of what we might expect at 3 psi from a megaton-yield weapon? The answer is NO. For a 5-MT detonation, the positive phase of the blast wave lasts 5 times longer than in this test. Not only would we expect the roof panels to be thrown much farther but the entire roof structure would have been removed.

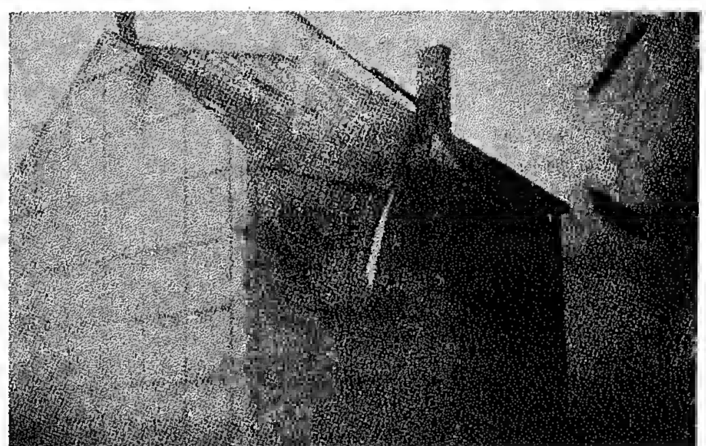
It is an unfortunate fact that past weapons test programs have yielded almost no direct data on blast damage to buildings for megaton-yield explosions. To remedy this lack of information, theoretical analyses have had to be supported by blast tests of a non-nuclear variety.



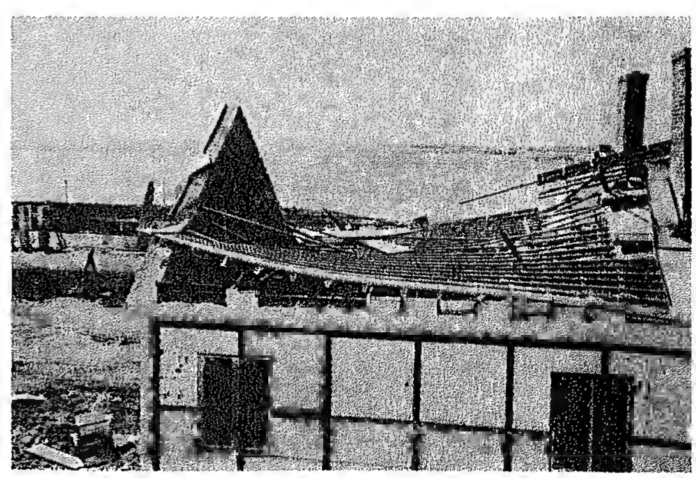
Impact



Impact + 0.6 second



Impact + 1.0 second



Afterward

PANEL 8

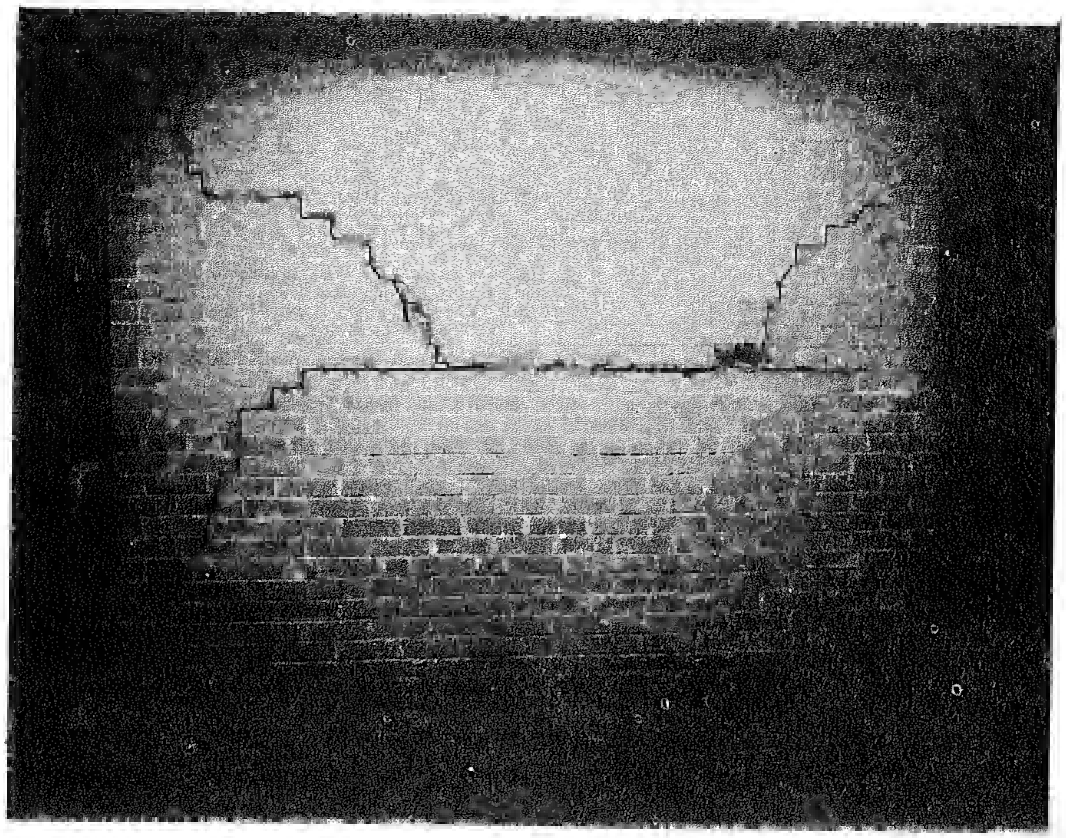
A TYPICAL BLAST EXPERIMENT

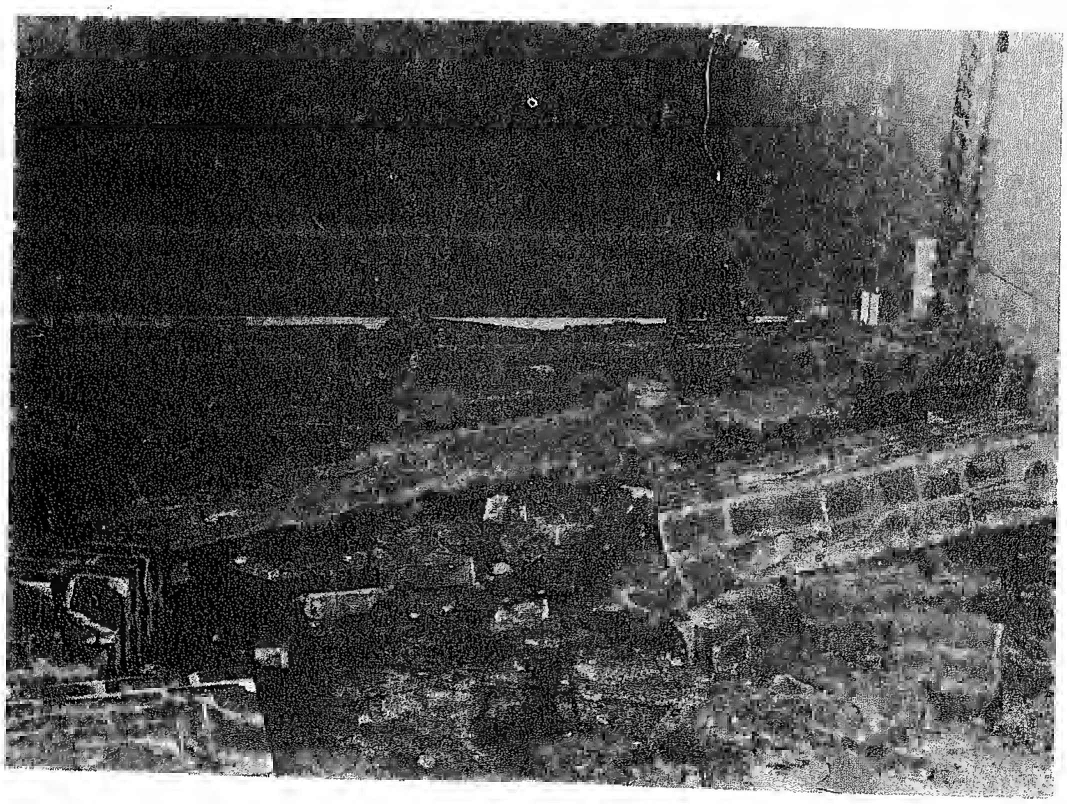
For the past several years, DCPA has been investigating the way walls fail under blast loading in a "blast tunnel" that permits us to duplicate the long-duration peak overpressure loads caused by nuclear detonations in the megaton-yield range. Two typical results are shown here.

The upper figure shows a brick wall that is on the point of "incipient collapse" after blast loading. The wall failed horizontally near the middle of the wall. The peak overpressure in this test was about 1½ psi.

The lower figure shows a similar brick wall after exposure to 3 psi overpressure. The wall has been thrown many yards down the tunnel, breaking into many small pieces in the process.

These tests have given good information on the overpressures required to cause various types of walls to fail and how the size of the pieces vary with the incident overpressure. The particular walls tested here are typical of relatively weak masonry walls, often found in single-story commercial buildings and residences. Their weakness stems from the fact that they are not locked into a stronger frame at their edges. In some kinds of buildings, the brick walls are held rigidly in a surrounding frame. Such walls, called "arching" walls, are much stronger than those shown here. Tests have shown that, in many cases, these arching walls will withstand more than 10 psi overpressure, even though they are no thicker than those shown here. It usually requires a person familiar with building construction and some special training to distinguish "weak" masonry walls from "strong" masonry walls.





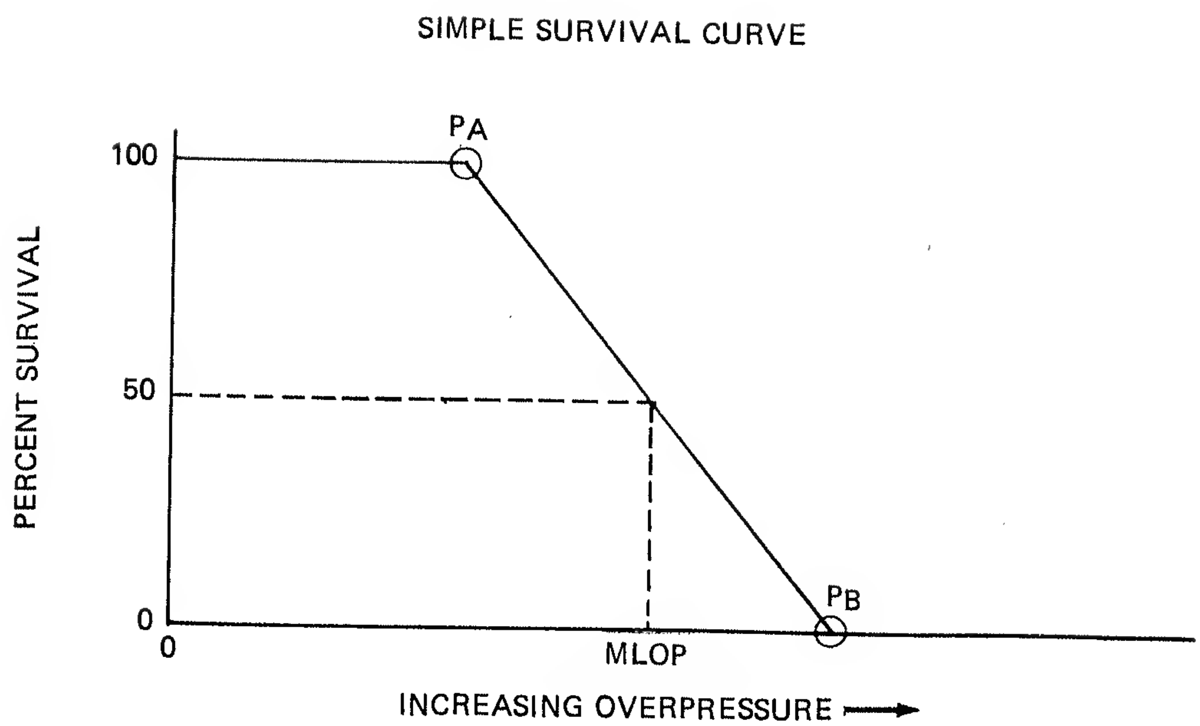
PANEL 9

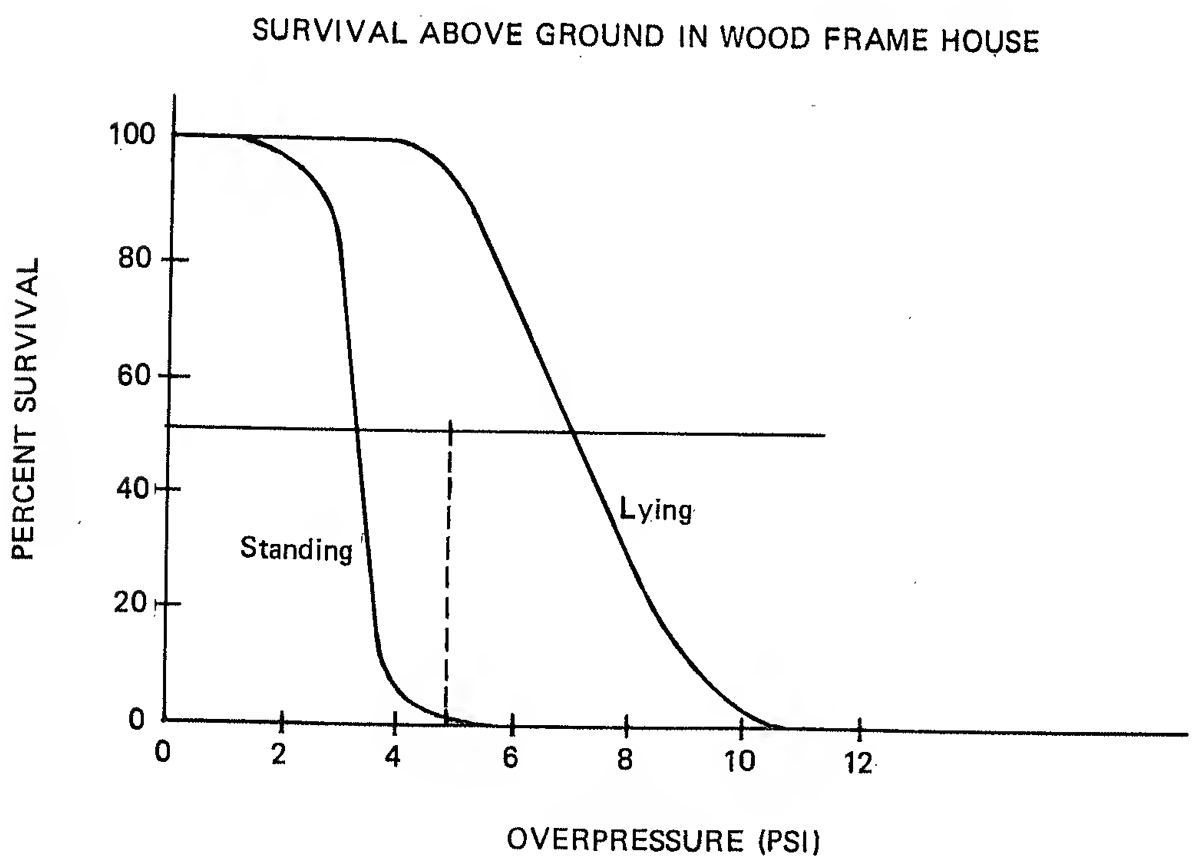
EFFECTS ON PEOPLE IN BUILDINGS

Estimating the survival of people in buildings has been a difficult problem. Blast casualties are related to building damage but to describe a building as "moderately damaged" says nothing about the survivability of the people therein. Two basic approaches to casualty estimation have been tried.

The first and oldest method has been to analyze carefully what happened to people in buildings at Hiroshima and Nagasaki in an attempt to estimate what would have happened to people in American buildings damaged by megaton-yield weapons. Thousands of detailed case histories have been studied. One difficulty has been to separate the blast casualties from casualties due to other effects, such as fire and initial radiation. A second, and more difficult problem has been to extrapolate the results to the long-duration blast wave of the megaton weapon. The first problem has proved easier than the second. The results are now suspect because they tend to give survival estimates that are inconsistent with the blast experiments just described.

The newer approach has been to break the casualty-producing mechanism into its constituent parts. The survival curve, in its simplest form, is shown here. People survive up to an overpressure, P_A, where the wall, for example, is at the point of "incipient collapse," shown in Panel 9. The overpressure, P_B, on the other hand, is well above the overpressure for complete building collapse because the blast wind must be capable of accelerating people and debris to impact velocities that would be lethal. To arrive at an estimate, careful calculations of the displacement of people and debris are made and compared with the specific injury and mortality data that has been obtained in animal experiments and at weapons tests. When we indicated in Panel 2 that the median lethal overpressure (MLOP) for people in aboveground parts of residences was 5 psi, the estimate was based on this type of calculation. Note in the lower sketch that 5 psi represents an average vulnerability. People standing are more vulnerable; people lying down are less vulnerable.


SIMPLE SURVIVAL CURVE
PA
100
50
0
PERCENT SURVIVAL
PB
0
MLOP
INCREASING OVERPRESSURE

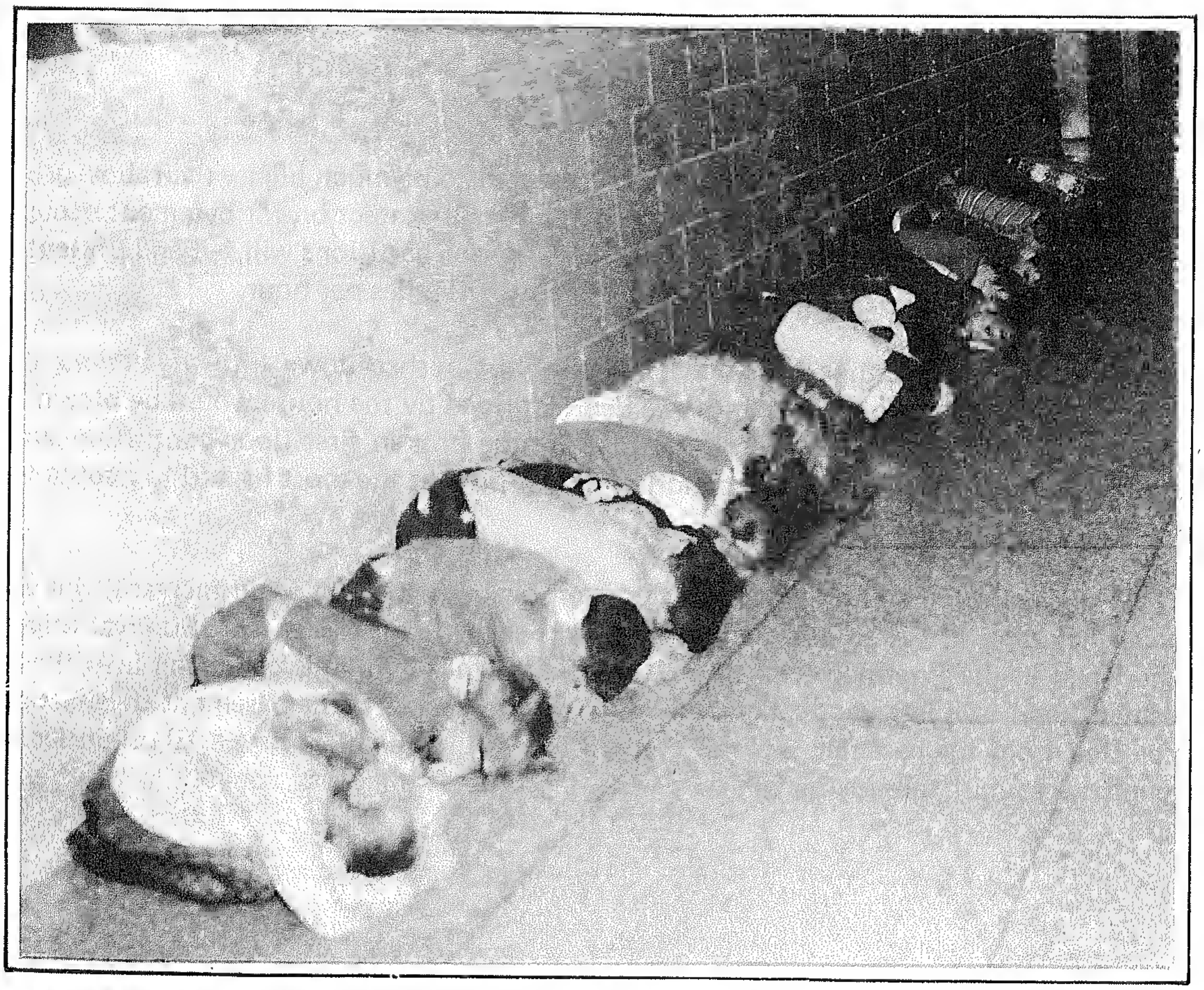

SURVIVAL ABOVE GROUND IN WOOD FRAME HOUSE
100
80
60
40
20
0
PERCENT SURVIVAL
Standing
Lying
0
2
4
6
8
10
12
OVERPRESSURE (PSI)

PANEL 10

PROTECTIVE ACTIONS

The newer method of casualty estimation can show the value of protective positions on the part of people. For example, it requires about 8 times the blast wind force to move a person who is lying down compared to a standing person. People crouched or lying down also offer a much poorer target to glass shards and debris missiles.

These school children are practicing a good protective posture to improve blast survival. Lying down would be even better. Calculations show that the median lethal overpressure (MLOP) in aboveground areas can be increased by 2 or more psi by these protective actions. The planner should recognize that a change in vulnerability of this magnitude can save many lives.



Photograph courtesy of The News—Virginia, Wayneboro, Virginia.

BLAST PROTECTION IN HOME BASEMENTS

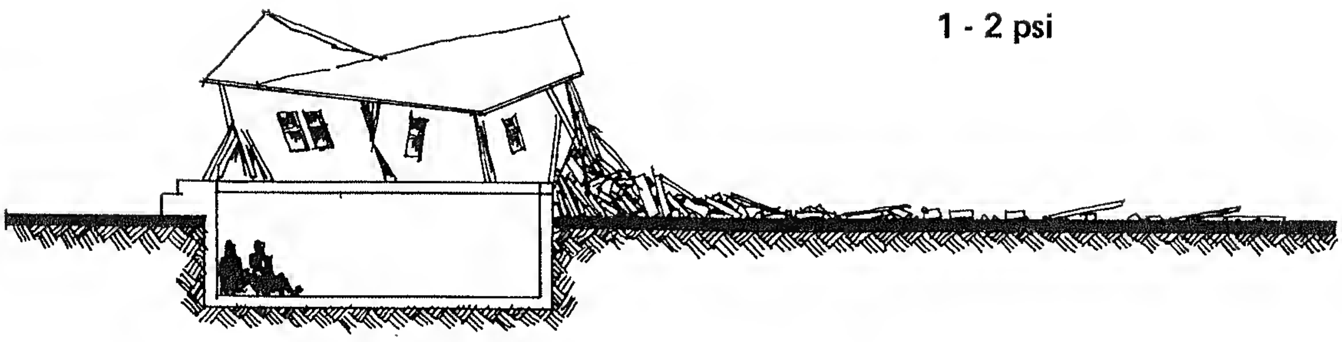
Blast survival in residential basements is estimated to be much higher than aboveground. As shown in the upper sketch, the first floor will provide protection for basement occupants at low overpressures where windows, doors, and interior partitions will fail and present missile hazards above. The blast wind would range up to 70 miles per hour.

At higher overpressures, the first floor would be pushed down into the basement. As shown in the middle sketch, much of the debris formed by the house would be blown from above the basement. Voids would be formed by the broken first floor permitting survival along the walls. This intermediate condition might present the most hazard to people in the basement.

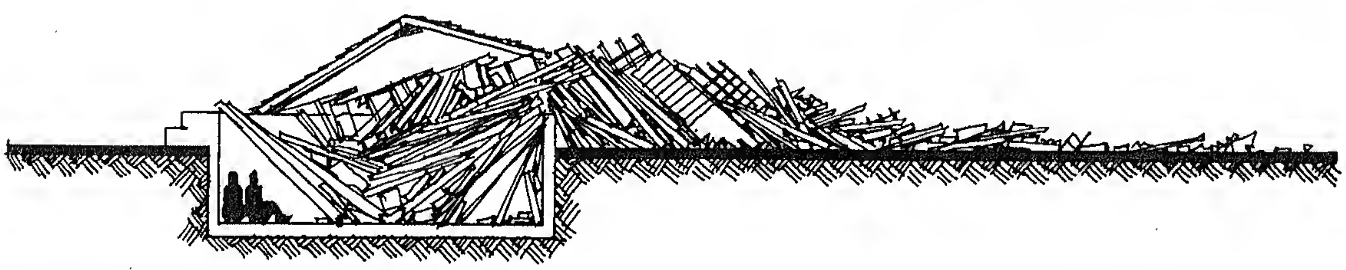
The lower sketch shows that, as the overpressure and blast wind increase, the whole house, including the first floor would be blown clear of the basement. Survival might be higher than in the intermediate case. Debris from other buildings could fall into the open basement, and, as blast winds increased above 300 miles an hour, basement dwellers could be ejected from the basement. Our best guess is that the MLOP might be 10 psi under these circumstances, but there is no definite evidence. The estimate is probably low rather than high.

HOME BASEMENT SHELTER

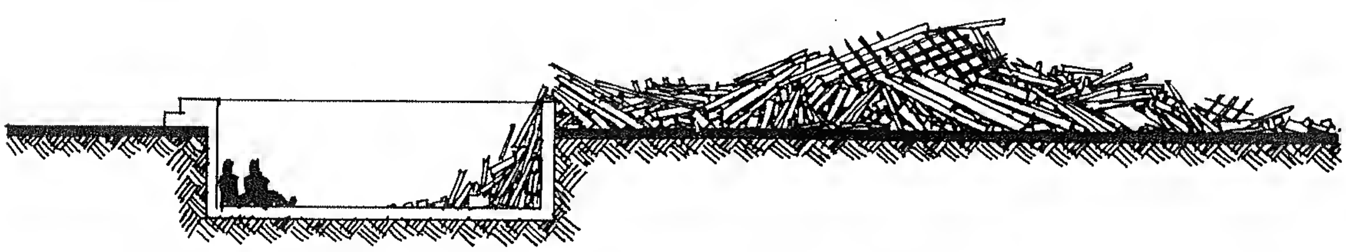
1 - 2 psi



2 - 5 psi



over 5 psi



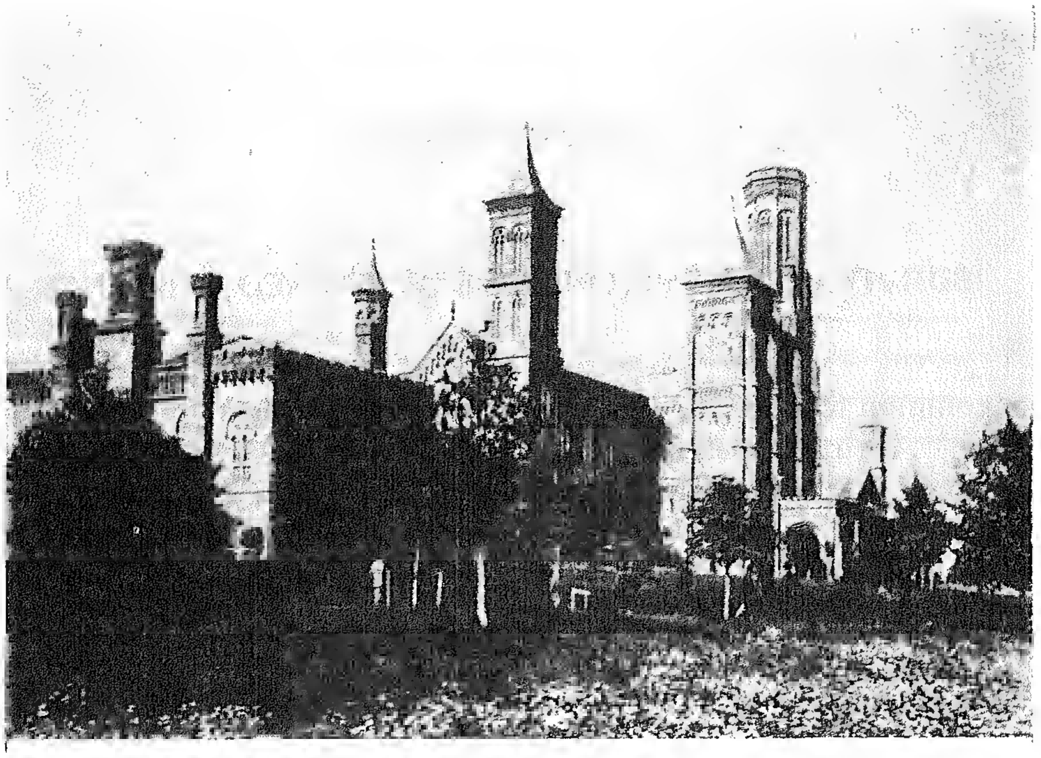
SURVIVAL IN LOAD-BEARING WALL BUILDINGS

Although the National Fallout Shelter Survey (NFSS) was not directed toward protection against direct effects, considerable information was gained on the structural characteristics of most large buildings in the United States. Additionally, a special statistical sample of NFSS buildings in five cities has been studied in great detail as part of a research program to develop an all-effects survey. The five cities—Providence, New Orleans, Detroit, Albuquerque, and San Jose (Calif.)—were chosen to exhibit a full range of regional and other urban characteristics.

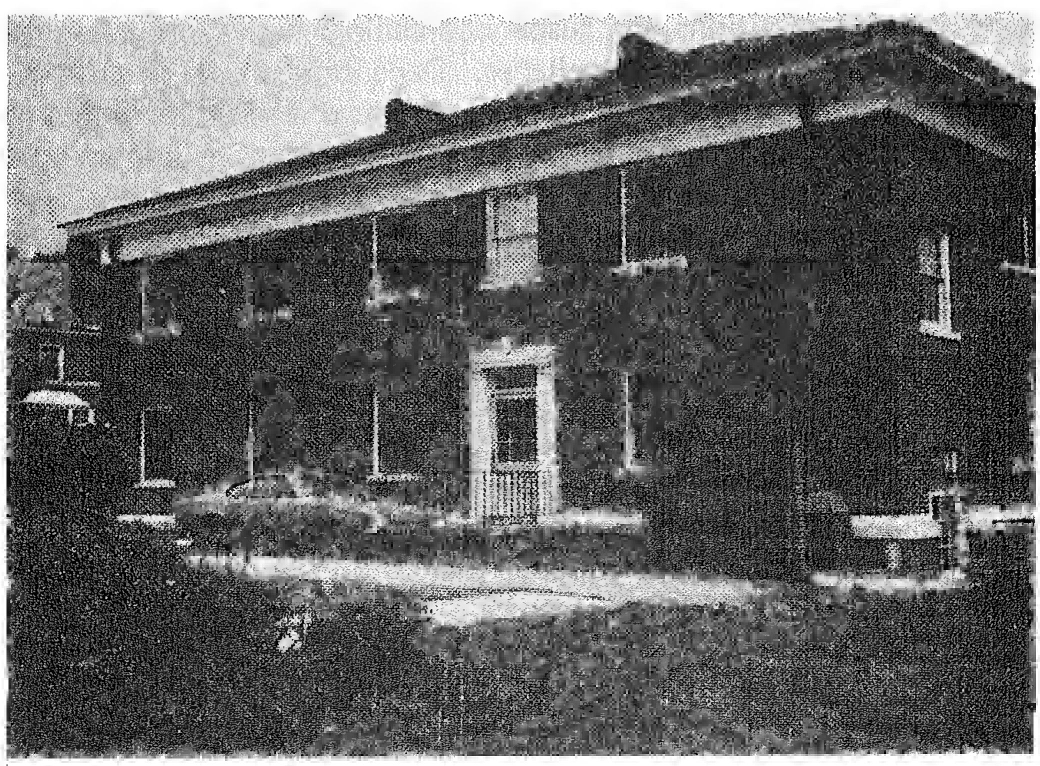
Many NFSS buildings have continuous masonry walls and partitions from the foundation to the roof. In these buildings, the floors are commonly supported by the walls. About half the large buildings in New Orleans, Detroit, and Albuquerque have load-bearing walls; about three-quarters are of this type in Providence and San Jose.

Some load-bearing wall buildings are of the monumental type, with massive walls that may resist overpressures of 10 psi or more. People lying near the exterior walls of the aboveground floors of such buildings would have better shelter than those in aboveground floors of most steel and concrete framed buildings. An example of a monumental-type structure is shown in the upper picture.

Most brick or masonry load-bearing wall buildings have little resistance to the lateral forces of overpressure and blast wind. The bearing walls tend to crack at about 4 psi, with collapse likely by 6 psi. The collapse of the exterior bearing walls results in collapse of most of the structure that is supported by them. Since the masonry debris is heavy, it is not thrown far by the blast wind gust. It is unlikely that the floor over the basement would be able to withstand the combined effects of the overpressure and the falling debris. Survival is about the same both aboveground and belowground in this type of building. Thus, except for monumental-type buildings, basements in load-bearing wall buildings are not much better than upper floors as protection against blast. A typical weak-walled brick apartment house is shown in the lower picture.



EXAMPLE OF MONUMENTAL MASONRY BUILDING



EXAMPLE OF WEAK LOAD-BEARING WALL BUILDING

PANEL 13

SURVIVAL ON UPPER FLOORS OF FRAMED BUILDINGS

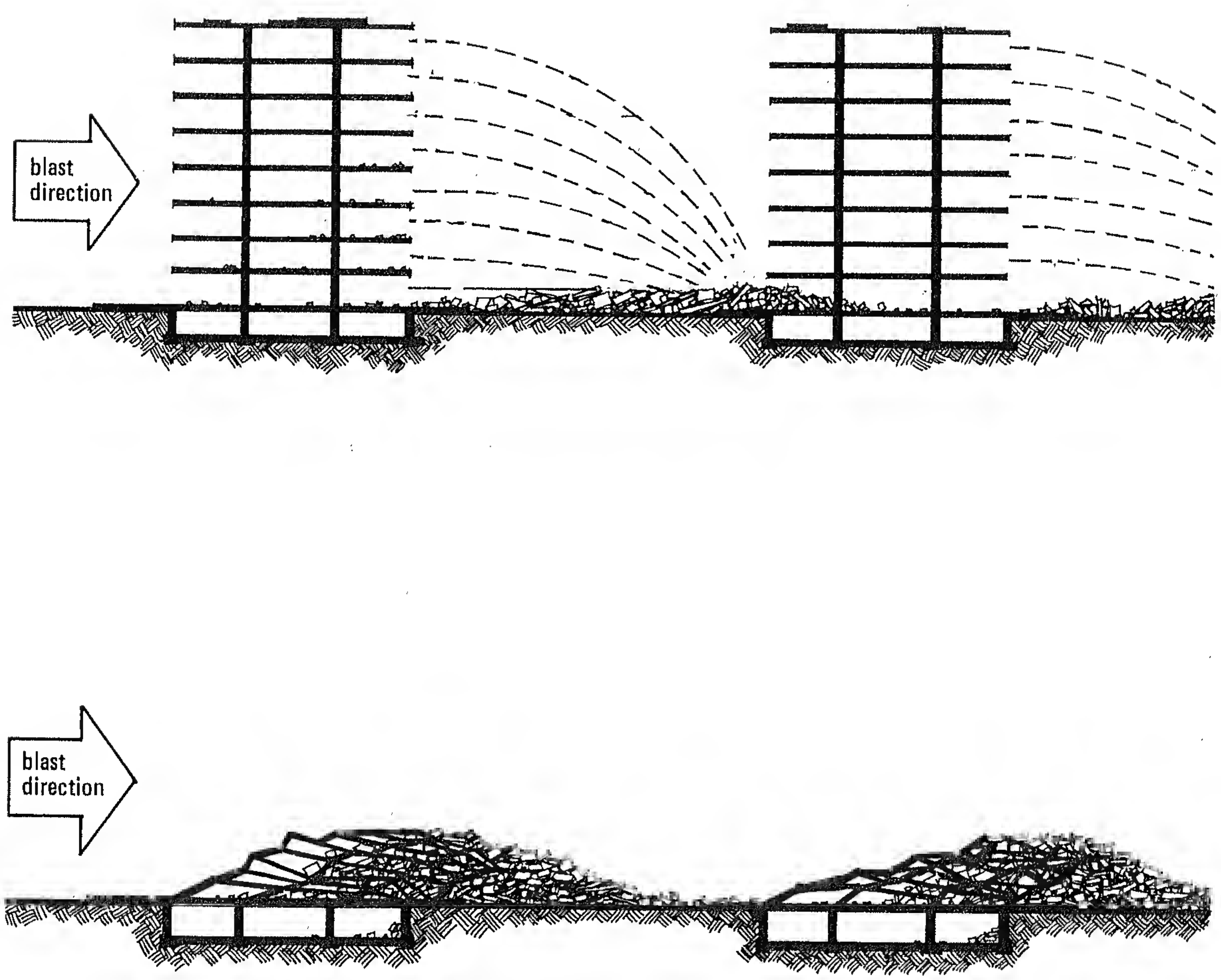
Another common form of large building construction is the reinforced-concrete or steel framed building. About 40 percent of the NFSS buildings in New Orleans, Detroit, and Albuquerque are of this type. Only about 20 to 25 percent of Providence and San Jose buildings are framed structures. Nonetheless, essentially all "high-rise" buildings in the five cities are of this type, containing large amounts of fallout shelter space on the upper floors.

The exterior walls of framed buildings tend to be very weak (2 - 3 psi), being simply mounted on supports attached to the building frame, or fairly strong (greater than 10 psi), actually built into the building frame to create an "arching" wall. In any event, at overpressures lower than those that would fracture the walls, people lying near the exterior walls would likely escape both flying glass and the jet action of the blast wave as it pours through the windows.

Damage to interior partitions and suspended ceilings would progress until, at higher overpressures, the exterior walls would collapse. Depending on the size of the building and the strength of the blast wind, some or all of the contents of each floor would be ejected out the far side of the building and would fall to the street below. The upper sketch shows two 8-story framed buildings separated by a distance of 100 feet. At overpressures high enough to sweep out the aboveground stories (4 to 10 psi) the contents of each story would follow somewhat the paths shown. Survival would obviously depend on not being above the third floor at the least.

At overpressures in excess of 10 psi, the structural frame, which would remain as a "drag-type" object, would be subject to collapse by the wind force. Failure would be as shown in the lower sketch. Note that, in a framed building, the basement does not receive a large debris load as is the case in the catastrophic collapse of a load-bearing wall building. Whether the basement suffers damage depends mainly on the ability of the first floor over the basement to withstand the blast overpressure.

FRAMED BUILDING



PANEL 14

PROTECTION IN BASEMENTS

As has been indicated, the basement areas of large buildings, particularly steel or reinforced-concrete framed structures, potentially offer good protection against blast. The most important consideration in this respect is the strength of the ground floor directly above the basement. Other considerations are the nature of exterior openings into the basement (apertures), whether the basement walls extend above the ground level, and the location of nearby buildings.

The structural statistics shown indicate that from 40 to 70 percent of NFSS buildings in the five city sample have no basement wall exposure. In other words, the floor above the basement is at ground level, a desirable situation. An even higher percentage, 60 to 90 percent, have no basement wall apertures. Entrances to the basement are internal to the building. This feature offers some advantages for blast protection but may complicate ventilation and access, particularly if the aboveground part of the building is damaged or demolished. About 40 to 70 percent of the buildings do not have common walls or immediately adjacent buildings. This means that these buildings are probably surrounded with streets, alleyways, or parking areas.

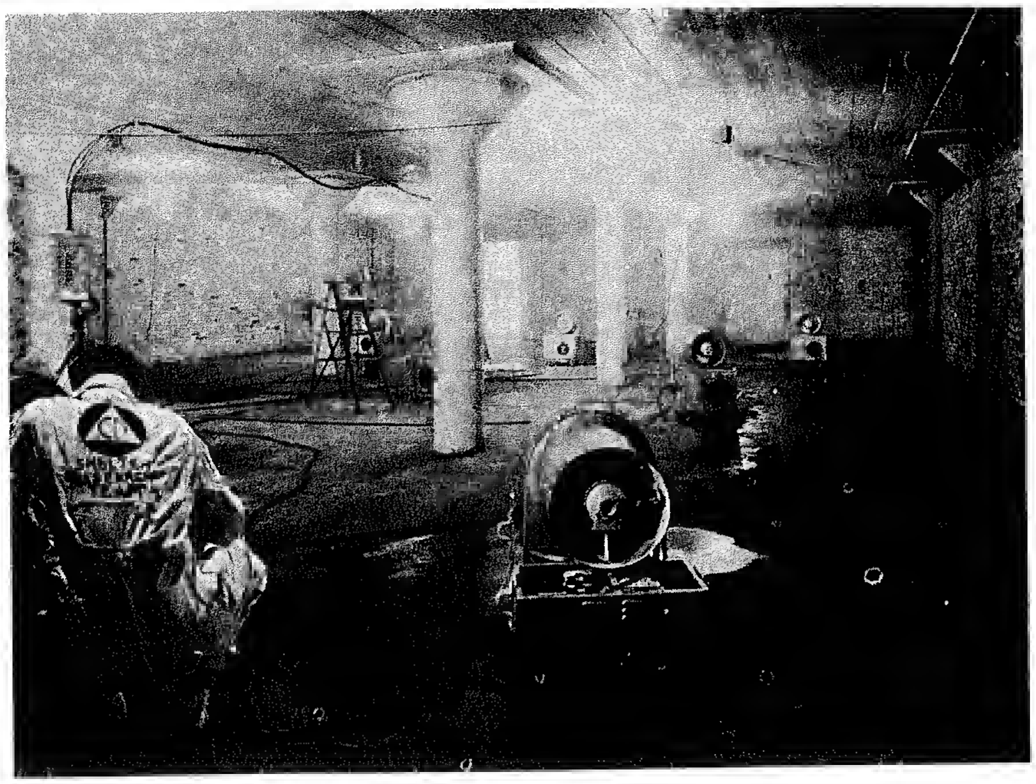
It goes without saying that a floor of wood or light steel framing above the basement offers little protection, unless the structure above is wood-frame or of other light construction. In that case, the protection is similar to that afforded by a home basement. Most ground floors are of reinforced concrete, supported by columns, pillars, or, occasionally, interior bearing walls. Typical load limits on first floors range from 100 to 150 pounds per square foot. This is equivalent to about 1 psi. Of course, large and usually unknown "factors of safety" enter into the floor design, which is intended to avoid any significant distortion. Major sagging, cracking, and distortion of the floor, on the other hand, would not necessarily result in major casualties among building occupants.

Older buildings were generally built in ways that enhance basement blast protection. Since World War II, however, building practices have emerged, generally in an effort to reduce labor costs, that meet building codes but offer much less blast resistance. It can be seen from the table that a majority of buildings in Providence, New Orleans, and Detroit were built before 1945. In the newer cities of the west, only about one-third are of pre-war construction.

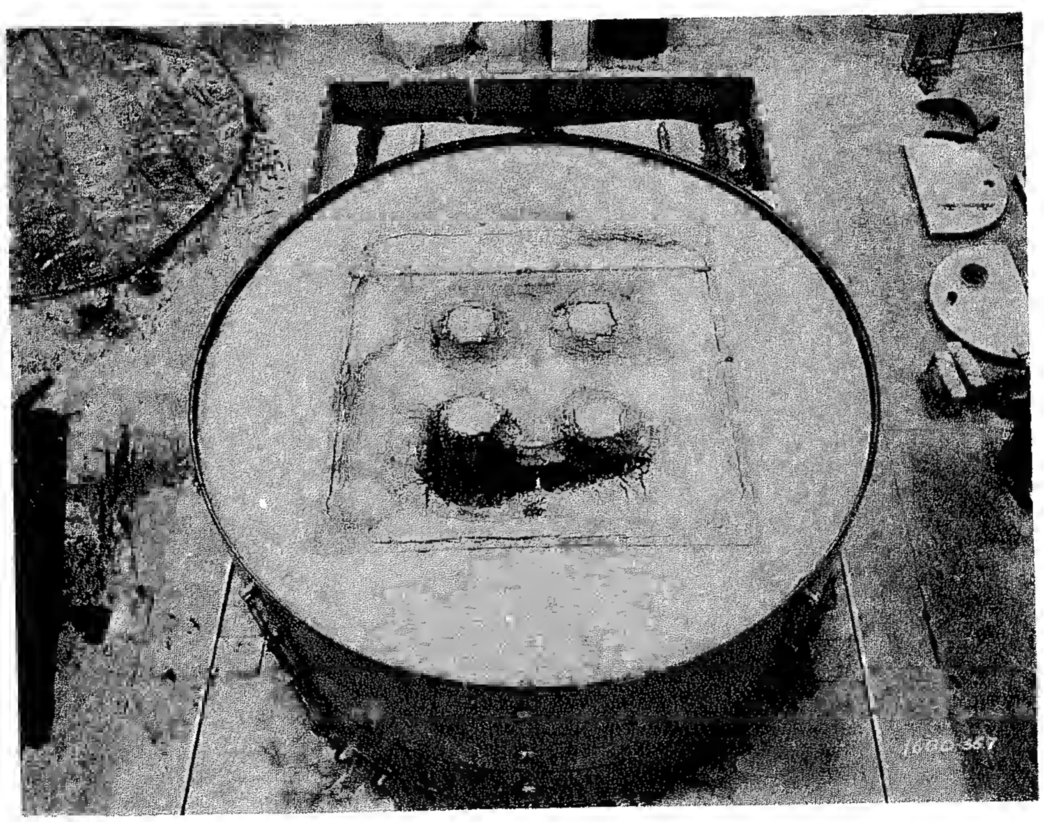
SELECTED STATISTICS

Characteristic	Percentage of Buildings with Characteristic				
	Providence	New Orleans	Detroit	Albuquerque	San Jose
Contains Basement	96	44	94	93	87
Framed Building	20	37	41	40	24
No Basement Wall Exposure	39	40	62	37	68
No Basement Wall Apertures	61	59	74	76	86
No Immediately Adjacent Buildings	72	44	37	73	47
Built Before 1945	51	73	82	27	36

FLAT SLAB FLOOR



UNDERSIDE OF FLAT SLAB



BLAST FAILURE OF FLAT SLAB

PANEL 16

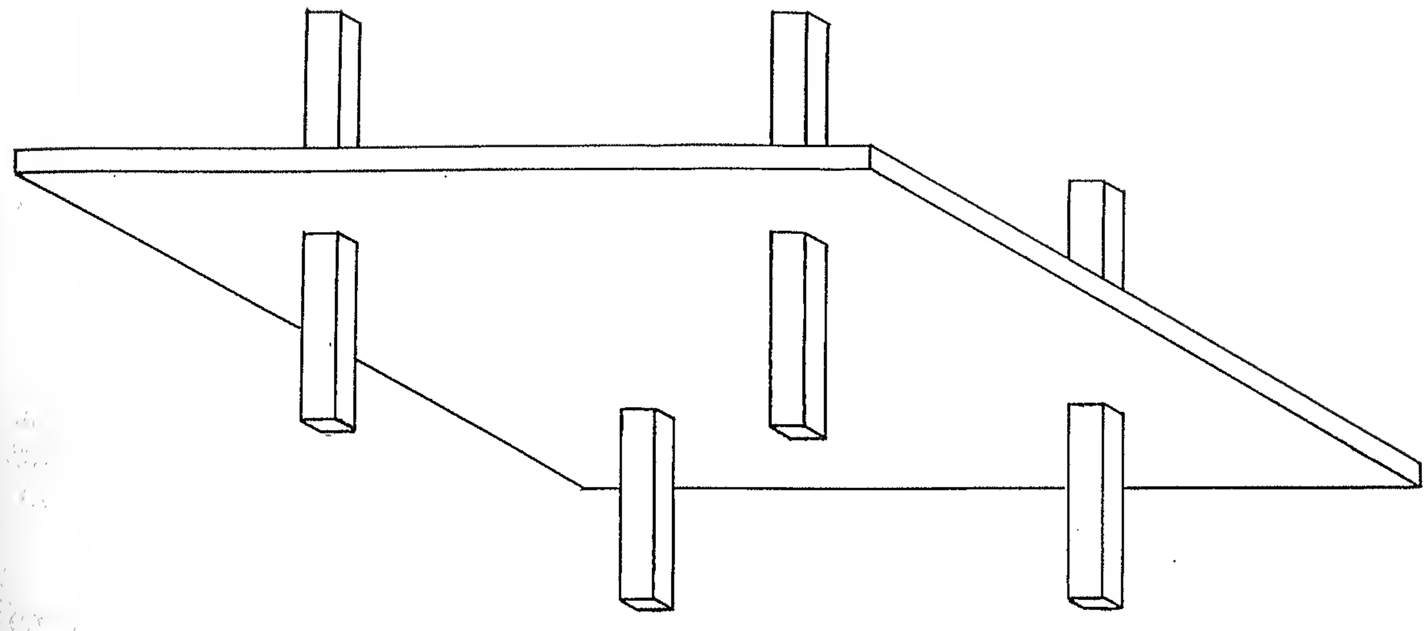
POORER BASEMENT SHELTER

Since about 1950, and at an increasing rate, a type of floor construction called "flat plate" has supplanted the flat slab and slab and beam types of construction. Flat plate construction is adequate to meet the design loads and is much more economical. As shown in the upper sketch, the floor is supported only at the columns. To compensate for this simplified construction, the floor itself is about twice as thick as in flat slab construction.

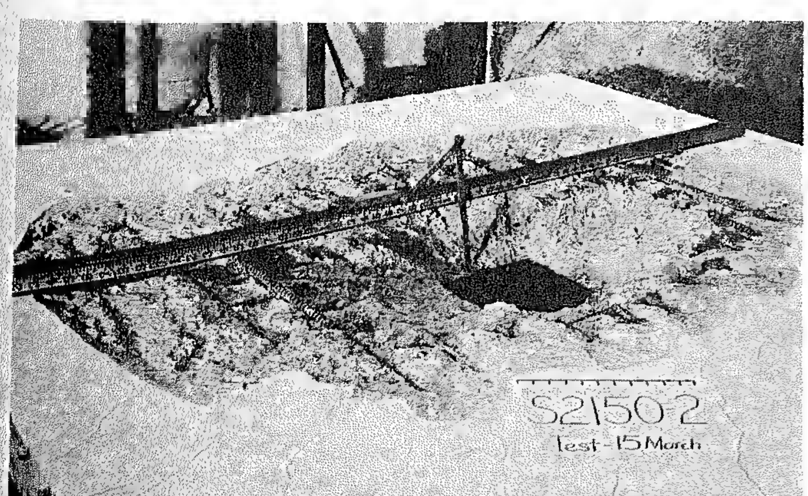
Under blast loading, stresses are set up that result in shear failure near the columns. The whole floor punches down into the basement, leaving a small portion at the top of the column. This catastrophic type of failure is shown in the two lower photographs. Failure is expected to occur at about 6 to 7 psi. While shelter in this type of basement is probably better than in the upper stories, this is one of the least blast-resistant types of basement.

Although only perhaps 10 percent of the basement space in the NFSS inventory is in buildings using flat plate construction, many of the newer buildings are built this way at the present time. Because they are new, your local building engineers probably have a good record of them.

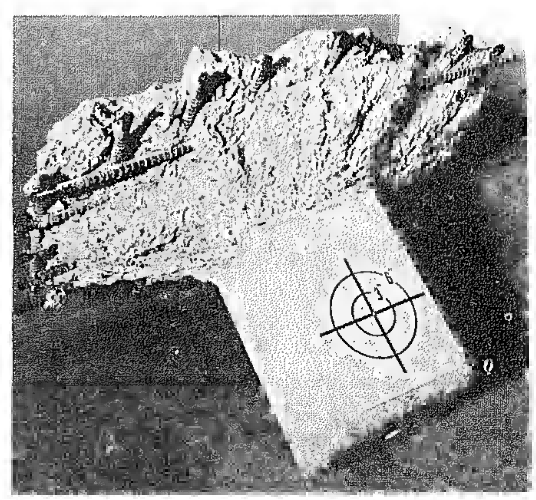
FLAT PLATE FLOOR



FLAT-PLATE SYSTEM



UPPERSIDE OF TEST FLOOR SHOWING FAILURE AREA



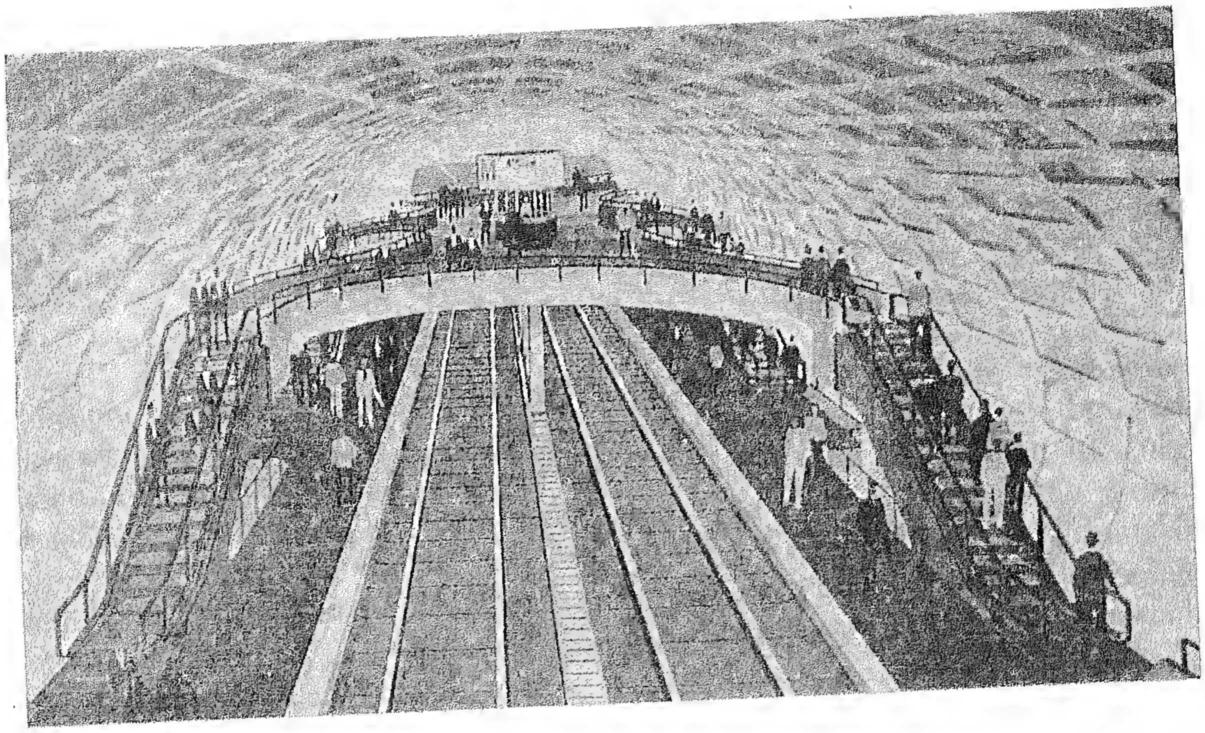
COLUMN AND FAILURE CONE

SUBWAYS, TUNNELS, MINES, AND CAVES

About 12 million fallout shelter spaces have been identified in underground areas, both man-made and natural. Nearly all of these areas offer good blast protection as well. The Soviet Union has emphasized the use of subways as blast shelters in cities. They have provided blast doors in the entrances to the subway station.

Most underground structures are stronger than building basements against blast loading. A recent analysis of a subway station being built in Washington, D.C., indicated that it could withstand an overpressure of 100 psi. Without blast doors, survival might be limited to 30 or 40 psi because of the blast wave entering through entrances and ventilation openings.

Underground subways and tunnels usually contain a large volume of air. When the blast wave enters through relatively small openings into a large-volume space, the blast wave overhead will pass by before the chamber has time to fill. This means that the pressure rise is relatively slow, which increases survival chances, and the overpressure inside may never reach the outside peak overpressure.



PANEL 18

BEST AVAILABLE BLAST SHELTER

The discussion to this point should provide some insight into how existing buildings and underground areas can best be used to increase blast survival. Identifying best available shelter against the blast hazard is a fairly technical task and, we admit, not nearly enough is known to do it with precision. In lieu of professional assistance, we offer the table shown here. It lists in order of survivability the various shelter locations that could be considered by the emergency planner. Using the space represented near the top of the list is preferable to using that near the bottom of the list.

One cautionary note should be sounded. Attempting to move people considerable distances to gain shelter is unwise in blast-prone areas. There may not be enough warning time. Increasing the population density in downtown areas is also a questionable tactic, even if the better shelter is there. The ideal movement plan is one that moves people as little as necessary and, in general, in the direction of the more sparsely populated parts of an urban area. Unfortunately, there is no easy way to compare the value of better shelter with the value of a more widely distributed population. Many studies have shown, however, that sending the daytime population home is "good" civil defense. Since even the work force is at home about 70 percent of the time, emphasis should be on locating suitable basement space close to where people live. An implication for planning is that residential basement space is of great potential value.

RELATIVE BLAST PROTECTION

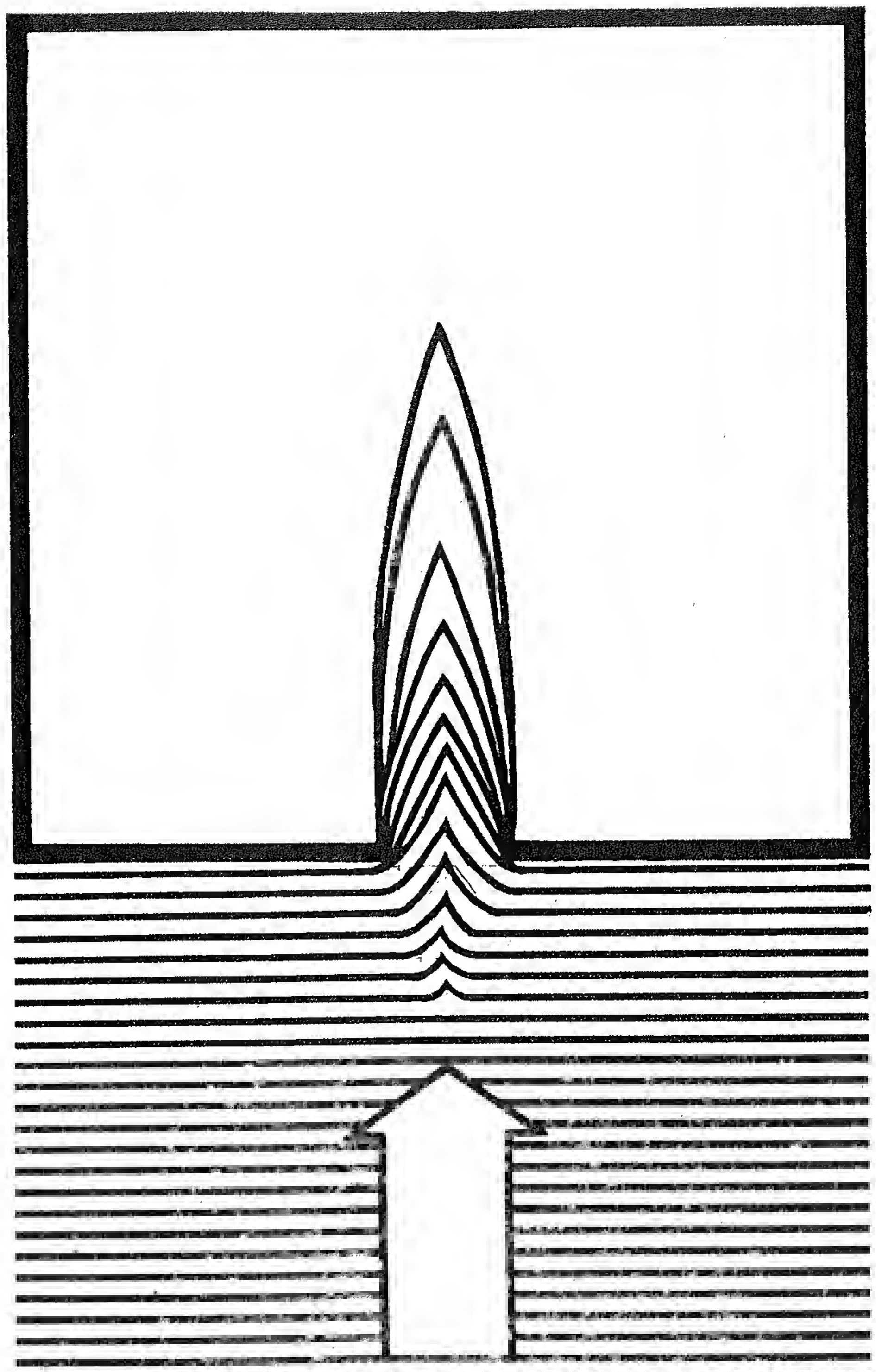
Preference	Description
A	Subway stations, tunnels mines, and caves with large volume relative to entrances.
B	Basements and sub-basements of massive (monumental) masonry buildings.
C	Basements and sub-basements of steel and reinforced-concrete framed buildings having flat slab or slab and beam ground floor construction.
D	First three floors of buildings with "strong" walls.
E	Basements of wood-frame and brick-veneer residences.
F	Fourth and higher floors of buildings with "strong" walls.
G	Basements of steel and reinforced-concrete framed buildings with flat plate ground floor.
H	First three floors of buildings with weak walls, brick buildings and residences
I	Fourth and higher floors of buildings with weak walls.

PROTECTIVE POSTURE FOR BLAST SURVIVAL

As noted previously, being thrown by the blast wind is the main source of injury and death in aboveground locations. Lying down rather than standing up is the preferred protective posture and would save many lives.

In basement areas, the hazard situation is somewhat different. People in basements will be subjected to severe wind forces only for as long as it takes the blast overpressure to fill the basement volume. The blast wave would enter through stairways, ventilation ducts, and other openings. In most basements, the filling process would be complete in several tenths of a second as compared to the several seconds of wind gust aboveground. In the vicinity of the major openings, however, the compressed air behind the shock front will rush into the shelter in the form of a high velocity air jet, as shown in the sketch.

The velocity in the jet can be sufficient to cause impact injury and death for a distance up to 10 times the width of the entranceway. In planning the use of basement areas, this hazard should be taken into account. The best location for people is near the exterior wall of the basement, out of the line of the entranceways. This location also takes advantage of the failure pattern of the ground floor over the basement. Since good basement space will usually be at a premium, people should be close-packed in a sitting position, with children sitting between the legs of adults. This protective posture can be maintained for several hours after the shelter is occupied. If people must be located in more hazardous areas, they should be encouraged to lie prone.



SHOCK WAVE

PANEL 20

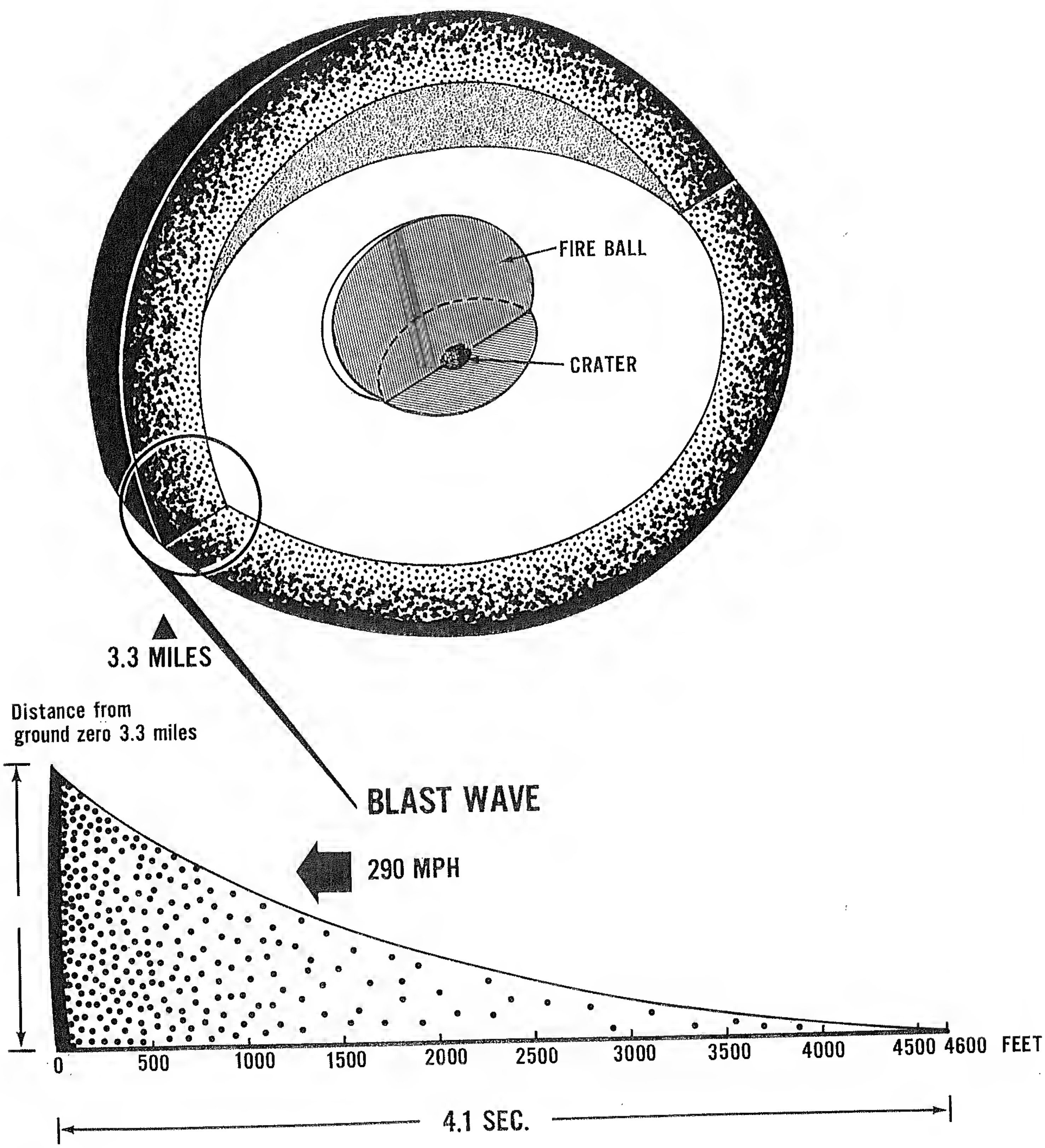
EFFECTS OF GROUND SHOCK ON PEOPLE

Up to now, we have ignored the pressure wave propagated through the earth by a nuclear detonation. The reason is that ground shock causes little damage in the "low overpressure" region with which civil defense planners are concerned. However, the ground shock should be considered in positioning people in basements.

There are two sources of ground shock. A surface burst imparts a portion of its energy directly to the ground, forming a crater and creating a "direct" shock wave. This direct shock decays rapidly as it expands outward into the ground. Additionally, the advancing air blast wave exerts intense pressures on the ground beneath it. As shown in this sketch, the blast wave is pressing down on a circular band of ground nearly one mile wide when the peak overpressure is 10 psi. It is continuously generating a wave in the ground that has a duration about the same as that of the air blast wave itself. This "air-induced" ground shock cannot affect aboveground portions of buildings as much as the air blast wave itself. But belowground portions can be moved suddenly for small distances, possibly causing injury to people if they are leaning against the basement wall. Therefore, people should be positioned near but not against the exterior wall.

A good plan for positioning people in basements is to have them sit back-to-back in a double row, with one row facing the basement wall. Injury through the soles of the feet is unlikely if the knees are bent. By using two back-to-back rows, with children between the legs of adults, people can be "packed" into the safest parts of the shelter area, leaving the central area and areas near entrances free. An on-site survey of each basement should be made to determine how many people could be accommodated in this fashion.

5 MT SURFACE BURST



DAMAGE FROM GROUND SHOCK

Air blast overpressure and the associated wind gust will cause most of the damage in the "low overpressure" region of interest to civil defense planners. The ground motion produced by the passage of the blast wave will, however, have some consequences. The surface overpressure generates a compressive wave that travels through the soil. The differential motion of the soil can stress underground piping at joints and connections. The ground shock wave also compacts the soil. Differential settlement and soil "liquefaction" can occur in "poor" soils. Filled land and areas with a high water table are especially vulnerable.

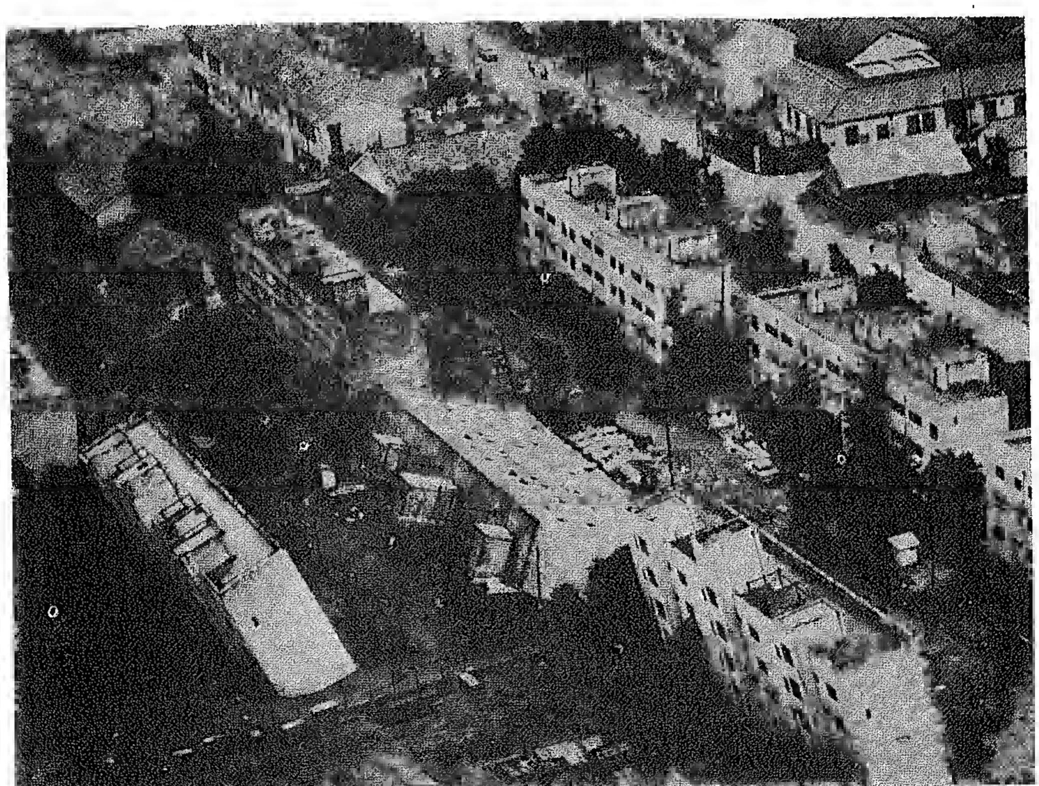
Generally, underground piping will not be seriously disrupted below an overpressure of 10 to 15 psi. It must be remembered, however, that failure in buried piping occurs in peacetime from traffic loads and other causes, especially in older water, gas, and sewer systems. Therefore, sporadic failures are to be expected in lower overpressure areas. Breaks in water mains under streets can result from cave-ins as shown in the upper photograph. There is some similarity between earthquake damage and the air-induced ground shock of a nuclear detonation, although the mechanisms are different.

Differential settlement of the ground and liquefaction can adversely affect the foundations of large buildings. Loss of bearing support can contribute to the tendency of relatively strong-walled buildings to overturn under the pressure of the air blast wave and wind loading. An earthquake example of this type of damage is shown in the lower photograph.

There is also some evidence that long-range ground motion can cause window breakage and other minor damage beyond the area of breakage from air blast.

GROUND MOTION DAMAGE

STREET CAVE-IN, ANCHORAGE ALASKA EARTHQUAKE, 1964



TILTED APARTMENT HOUSE AFTER EARTHQUAKE IN NIIGATA, JAPAN

PANEL 22

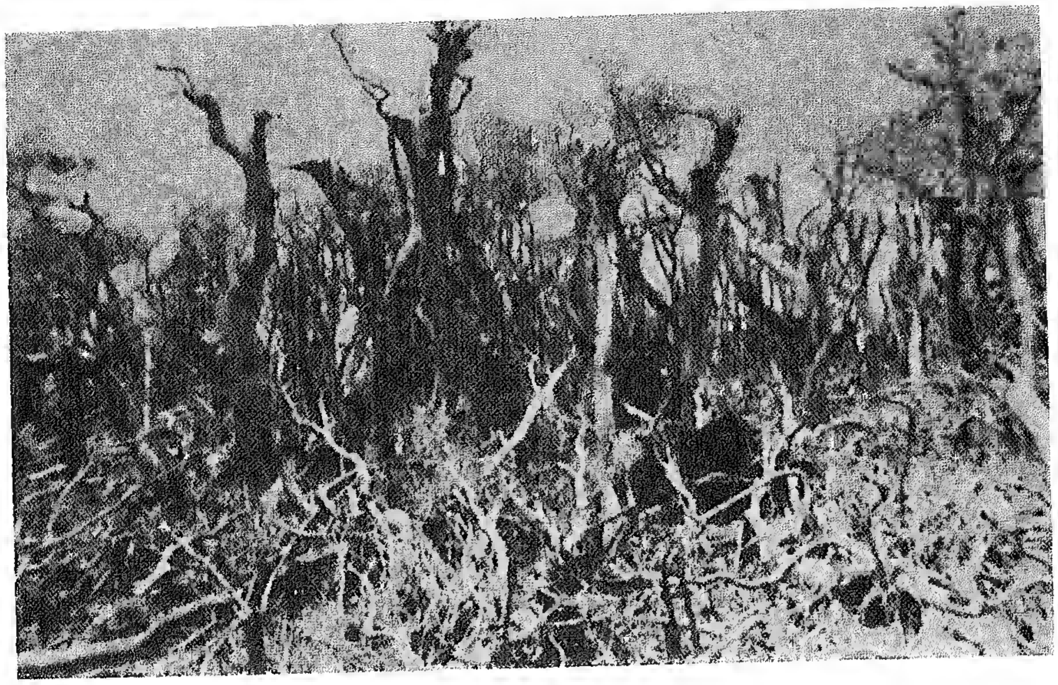
DAMAGE FROM BLAST WIND

Trees, utility poles, and radio antenna towers are "drag-type" structures, principally damaged by the blast wind. Trees are less vulnerable in winter than when in full leaf. The 70 miles per hour wind associated with 2 psi overpressure will tear off many branches. At 3 psi (100 mph wind) shallow-rooted trees and those in cities with constricted roots will be blown down. The upper photograph shows wind damage to trees resulting from a megaton weapons test. Few trees will be standing above 5 psi overpressure.

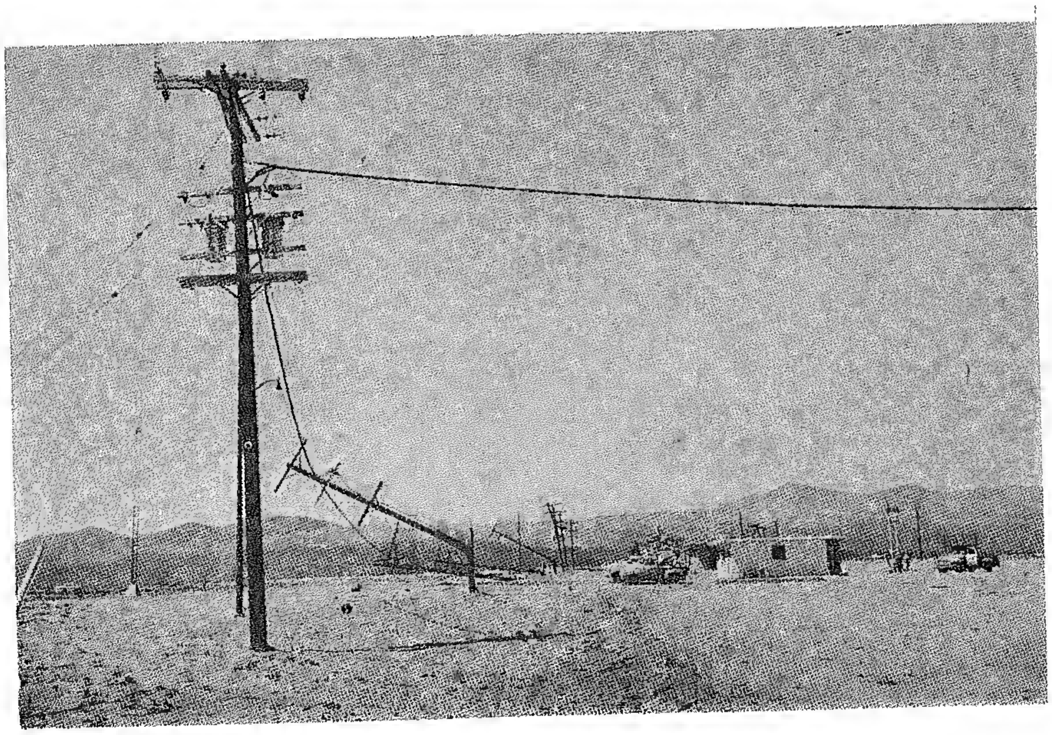
Utility poles and transmission towers with lines transverse to the blast will collapse at about 3 psi. Lines radial to the blast will be brought down above 4 to 5 psi. Well-anchored antenna towers can resist the blast wind about as well as steel building frame, failing at 4 to 6 psi.

The lower photograph shows damage to a pole-mounted transformer in Nevada at 5 psi. This sort of damage can be expected at about 3 psi for the longer-duration blast wind of megaton-yield winds. Trees, poles, and signboards can add appreciably to debris clogging access routes for emergency operations.

BLAST WIND DAMAGE



DECIDUOUS FOREST SUBJECTED TO 2.4 PSI FROM A MEGATION
–RANGE WEAPON. NOTE EXTENSIVE CROWN BREAKAGE



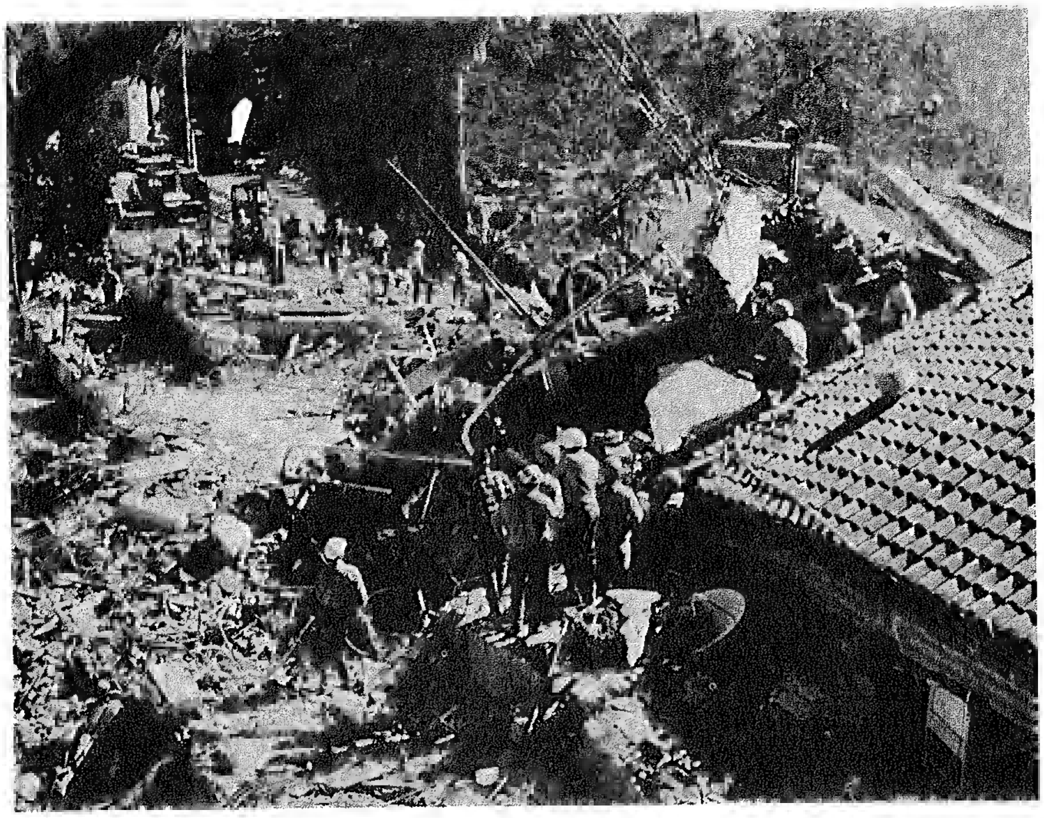
UTILITY POLE DAMAGE AT 5 PSI AT NEVADA
PROVING GROUNDS

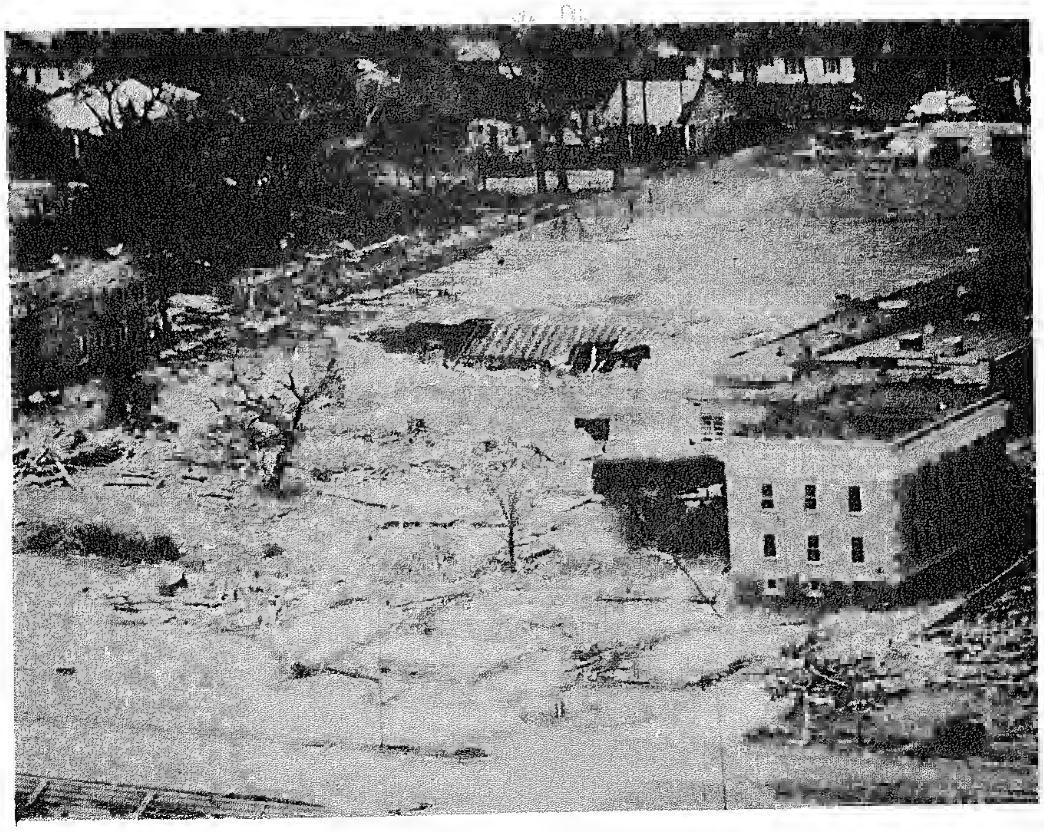
DEBRIS FROM NUCLEAR BLAST

This chapter has emphasized the importance of the long-duration blast wave from megaton-yield nuclear detonations. In particular, the persistence of the blast wind associated with the overpressure will distribute debris to large distances from the initial site. As a result, the debris from damaged buildings can be expected to be "off-site" rather than "on-site."

The upper photograph is of debris caused by the California earthquake of February 9, 1971. Parts of the building have collapsed directly on to the building site. This is not the situation to be expected as the result of a nuclear detonation.

The lower photograph shows debris near the water front at Pass Christian, Mississippi, following Hurricane Camille, August 1969. The floor slab of a building near the street at lower left is nearly clear of debris. Much debris is seen behind the original site, with the building roof several hundred feet further on. This example is more nearly like the action of the blast wind.





PANEL 24

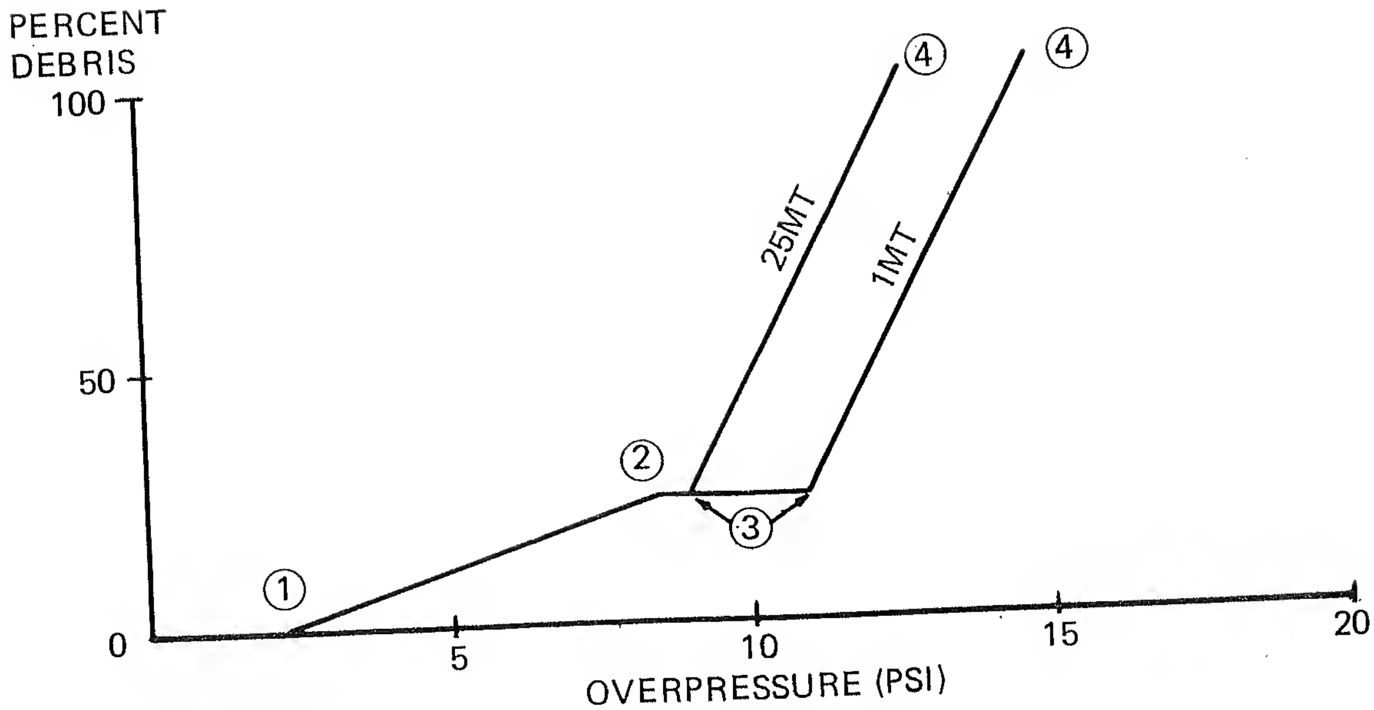
HOW DEBRIS IS RELATED TO DAMAGE

Unless a building is completely destroyed, only the parts of the structure that fail under blast loading plus the contents of the failed part of the building can become debris. Except for wood-frame and load-bearing masonry buildings, many buildings have relatively light walls and partitions that will fail at a much lower overpressure than the frame itself.

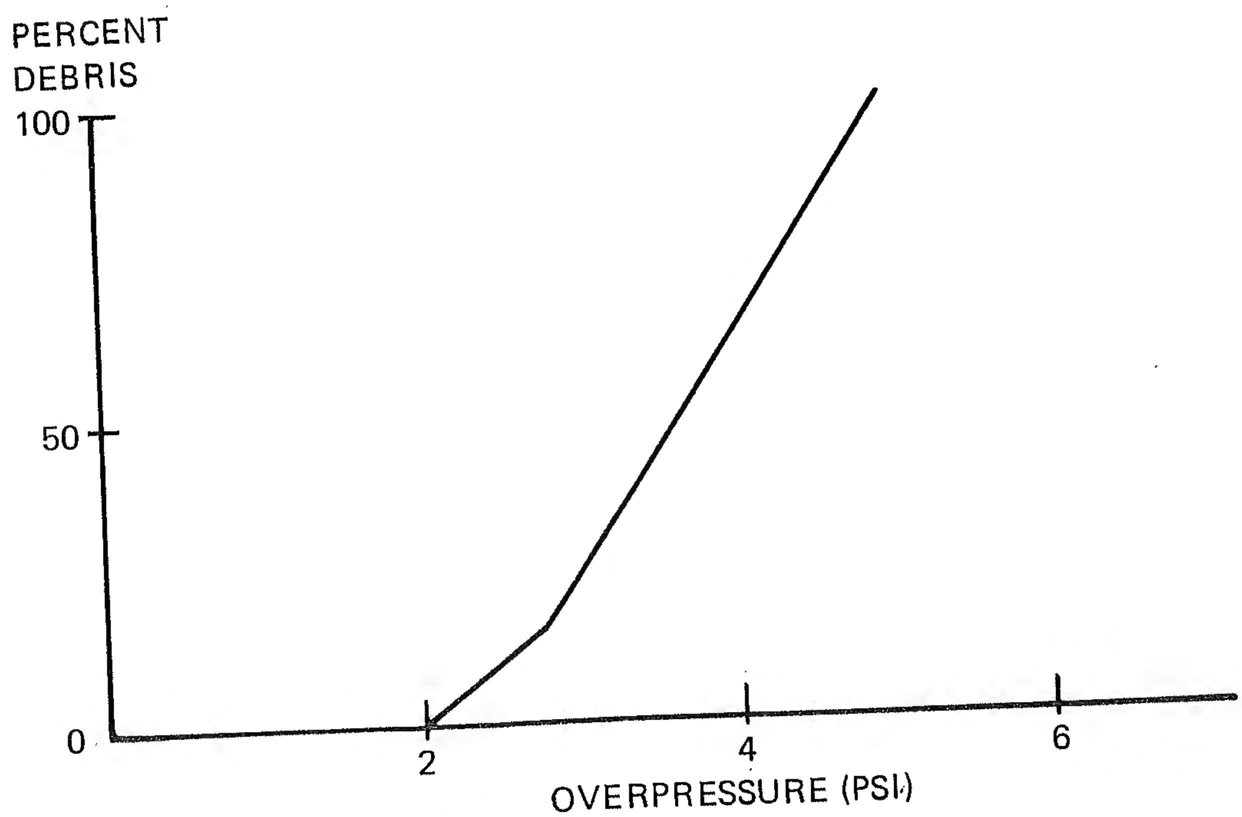
The upper sketch shows a typical "debris chart." Points 1 and 2 are the initiation and completion, respectively, of failure of the "frangible" elements of a building. The plateau between points 2 and 3 is caused by the differences in overpressure between final failure of the frangible parts (walls, etc.) and the start of failure of the "drag-sensitive" or ductile structure of the building. The location of points 3 and 4 is determined by the failure characteristics of the main structural system, which depend on the blast wind duration, and, hence, on the weapon yield. The chart shows the pattern for a multistory frame building for both 1-MT and 25-MT weapons. The height of the plateau is determined by the proportion of the total building represented by the frangible parts and the contents of the aboveground floors.

Wood-frame and masonry buildings have very little ductility and points 2 and 3 practically coincide, eliminating the plateau effect. The lower sketch is the current debris estimate for wood-frame buildings. Debris begins to form at about 2 psi and the building is completely collapsed at 5 psi. Debris is strewn off-site by 7 psi.

Masonry structures may fail at somewhat higher overpressures but the debris chart otherwise looks very much like that shown for wood-frame construction.



DEBRIS CHART FOR MULTISTORY STEEL OR
R.C. FRAMED BUILDING WITH LIGHT EXTERIOR PANELS



DEBRIS CHART FOR WOOD-FRAME BUILDING

PANEL 25

DEBRIS DEPTHS

The debris charts of Panel 25 were constructed by calculating the volume of structural material contained in the various building components and then estimating the part of these components that would become debris at a particular overpressure. The volume of structural material from buildings is relatively small compared with the volume occupied by the undamaged structure, generally less than one-tenth as much. The contents of buildings can also become debris. A rough rule of thumb is that the volume of contents as debris equals the debris volume of the structure. Additionally, the jumble of debris contains much void space, so the volume of debris is generally twice as much as the volume of the actual materials involved.

The structure and contents of a single-story frame residence represents 2 feet of material (and voids) over the plan area of the house. Of course, the debris would be spread over a much larger area of perhaps several hundred feet extent. Typical debris depths for the frangible parts and contents of a number of building types under these circumstances are shown in the table. It can be seen that debris depths may be quite small in many residential and industrial areas. In downtown areas of many high-rise buildings and relatively narrow streets, debris depths could be tens of feet deep. Should overpressures exceed that necessary to collapse the frames of tall buildings, they would "lay over" as in Panel 14, blocking the neighboring streets and areas away from the burst.

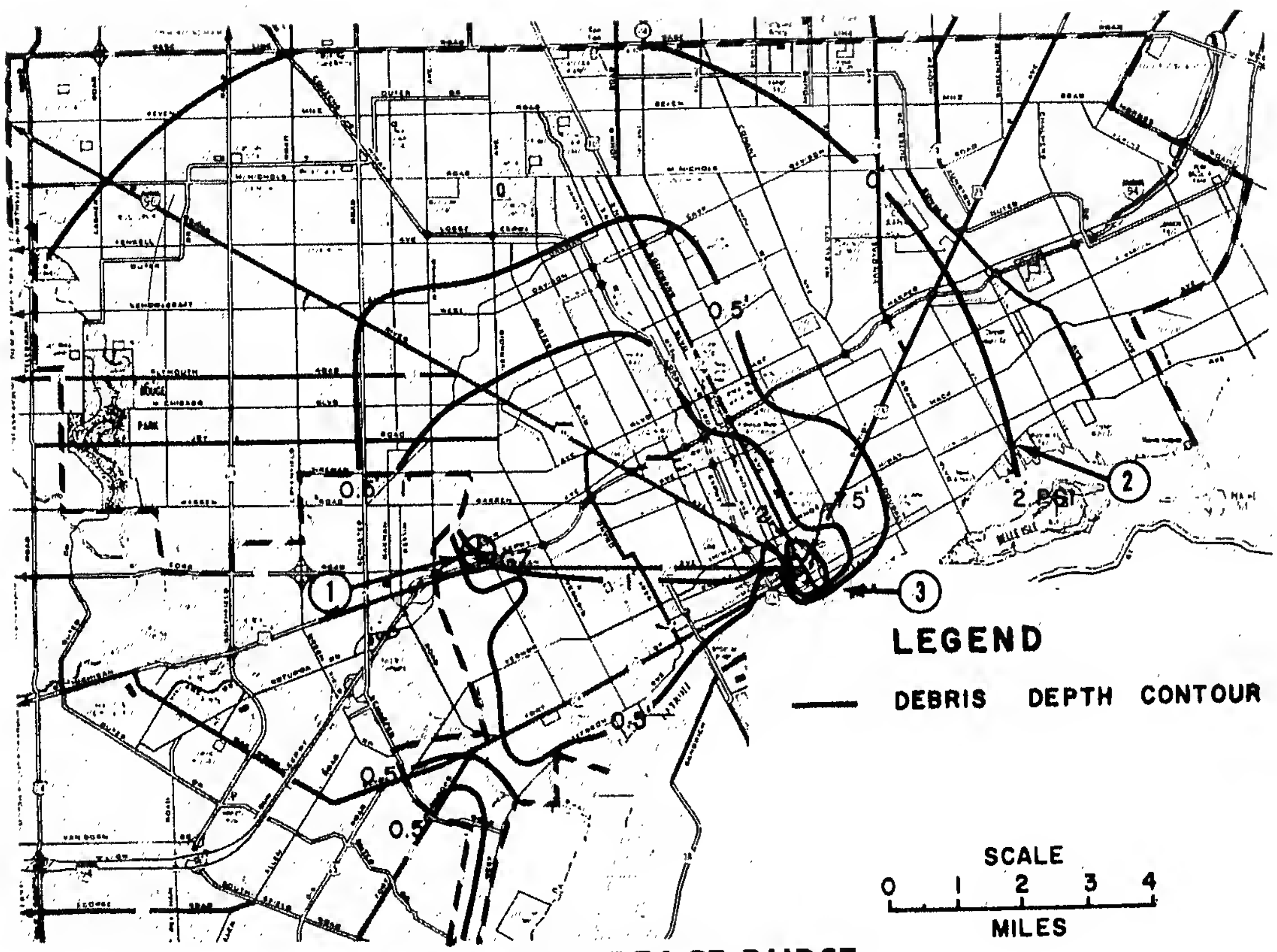
TYPICAL DEBRIS DEPTHS

Building	Average Debris Depth (feet)
One-story Industrial	0.3
Two-story Wood-frame Residence	0.5
One-story Brick Residence	0.5
Three-story Duplex or Row House	3.0
Five-story Steel-frame Apartment House	7.0
Twenty-three-story High-rise Building	33.0

BUILDING DEBRIS IN A CITY

This map shows an estimate of the blast debris resulting from a 5-MT surface detonation in Detroit. Arrow No. 1 points to the hypothetical Ground Zero. The limit of significant debris is taken to be the 2 psi line, indicated by Arrow No. 2. Most of the area has average debris depths of one foot or less, even close to Ground Zero. This reflects the type of buildings and built-upness involved. Only in the downtown area (Arrow No. 3) are streets obstructed by two or more feet of debris. The maximum estimate is about 7.5 feet. The downtown area was subjected to 4 to 5 psi in this case so the debris is mostly light walls, partitions, and contents of the many multistory buildings.

In the higher overpressure region, building debris may be distributed fairly uniformly. But, for the most part, the debris would be distributed away from Ground Zero. Therefore, wide streets, such as Michigan Avenue, Ford Road, and Livornois, that lead directly away from (or to) Ground Zero should be relatively free of debris except where overpasses are down. On the other hand, streets running across the damaged area are likely to be obstructed. Planning of emergency operations should take into account the accessibility features of freeways, parkways, and wide streets in areas of modest construction.

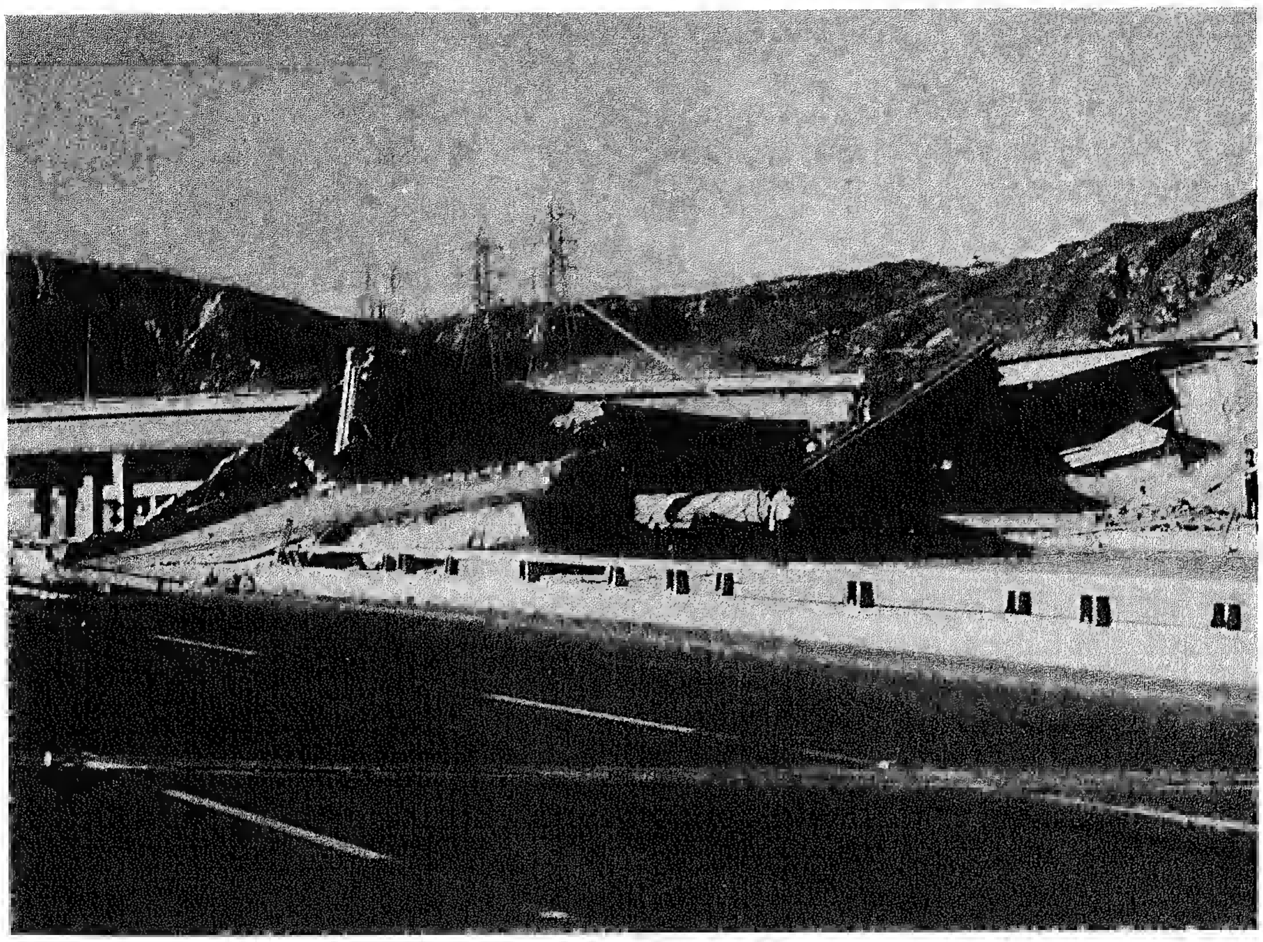


5MT SURFACE BURST
Debris Depth Contour Map (Air blast only)

DAMAGE TO BRIDGES AND OVERPASSES

Bridges and overpasses are important elements of accessibility in most urban areas. Emergency plans should take into account the vulnerability of these structures. The loss of a bridge not only blocks the road or rail route using the bridge, but also may obstruct the waterway or expressway over which the bridge passes.

Railway and highway truss bridges are quite resistant to blast, collapse occurring generally at 12 to 20 psi. Freeway overpasses are more vulnerable to destruction and may fail at overpressures of 7 to 10 psi. The photograph shown here is of freeway interchange damage resulting from the 1971 California earthquake.



FREEWAY INTERCHANGE DAMAGE
1971 CALIFORNIA EARTHQUAKE

DAMAGE TO VEHICLES

Destruction of transportation vehicles, fire trucks, and earthmoving equipment can hamper emergency operations. Damaged vehicles can impede movement on streets and make debris removal more difficult.

Damage to mobile equipment located inside or adjacent to buildings is dependent almost totally on damage to the buildings. Fire stations and garages are usually lightly constructed and fail at low overpressures. Moderate damage requiring several hours of repair work will usually occur at 2 to 4 psi. Above 4 psi, mobile equipment will generally be inoperable and trapped in building debris.

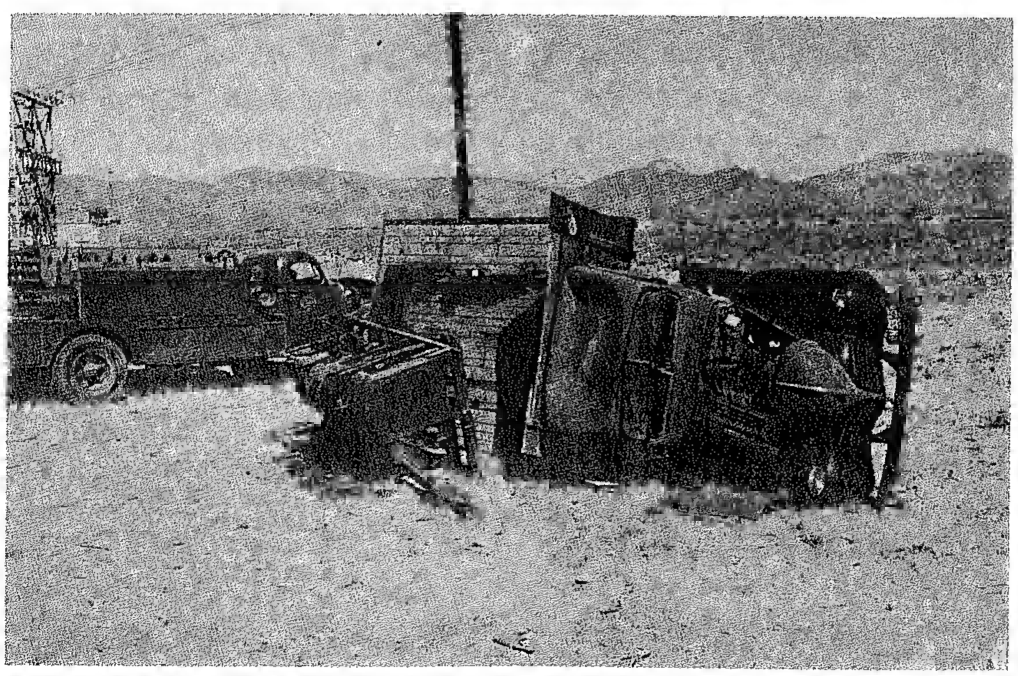
Vehicles parked in the open are significantly less vulnerable as shown on this chart. The amount of damage depends strongly on orientation to the blast. Vehicles broadside to the blast are likely to be overturned while vehicles end-on are not. The photograph shows typical damage at 5 psi in a Nevada test. Both trucks were operable.

A case study made of a 5-MT detonation in Albuquerque indicated that, with fire trucks parked in fire stations, 23 of 27 pieces of equipment were damaged, 11 of them beyond repair. If parked in an open parking lot with random orientation, only 11 were damaged, 7 of which could have been repaired.

The concept of a "multi-purpose" staging area has developed from considerations of this kind. Fire trucks, utility repair trucks, and debris-removal equipment would be parked at, say, a large shopping center, with the operating personnel taking shelter in the building basements. Coordinated emergency operations could then be undertaken following attack. even in areas of substantial damage.

VEHICLE DAMAGE

Type	Moderate Damage (psi)	Inoperable (psi)
Automobiles	3 - 5	5 - 6
Buses	6 - 10	10 - 12
Fire Trucks	6 - 10	10 - 12
Repair Trucks	6 - 10	10 - 12
Earth and Debris Moving Equipment	20 - 30	30 - 35
Truck-Mounted Engineering Equipment	12 - 15	15 - 17
Railroad Cars	15	25
Locomotives	30	80



Vehicle damage at 5 psi, Nevada Test Site; both vehicles operable.

DAMAGE TO URBAN UTILITY SYSTEMS

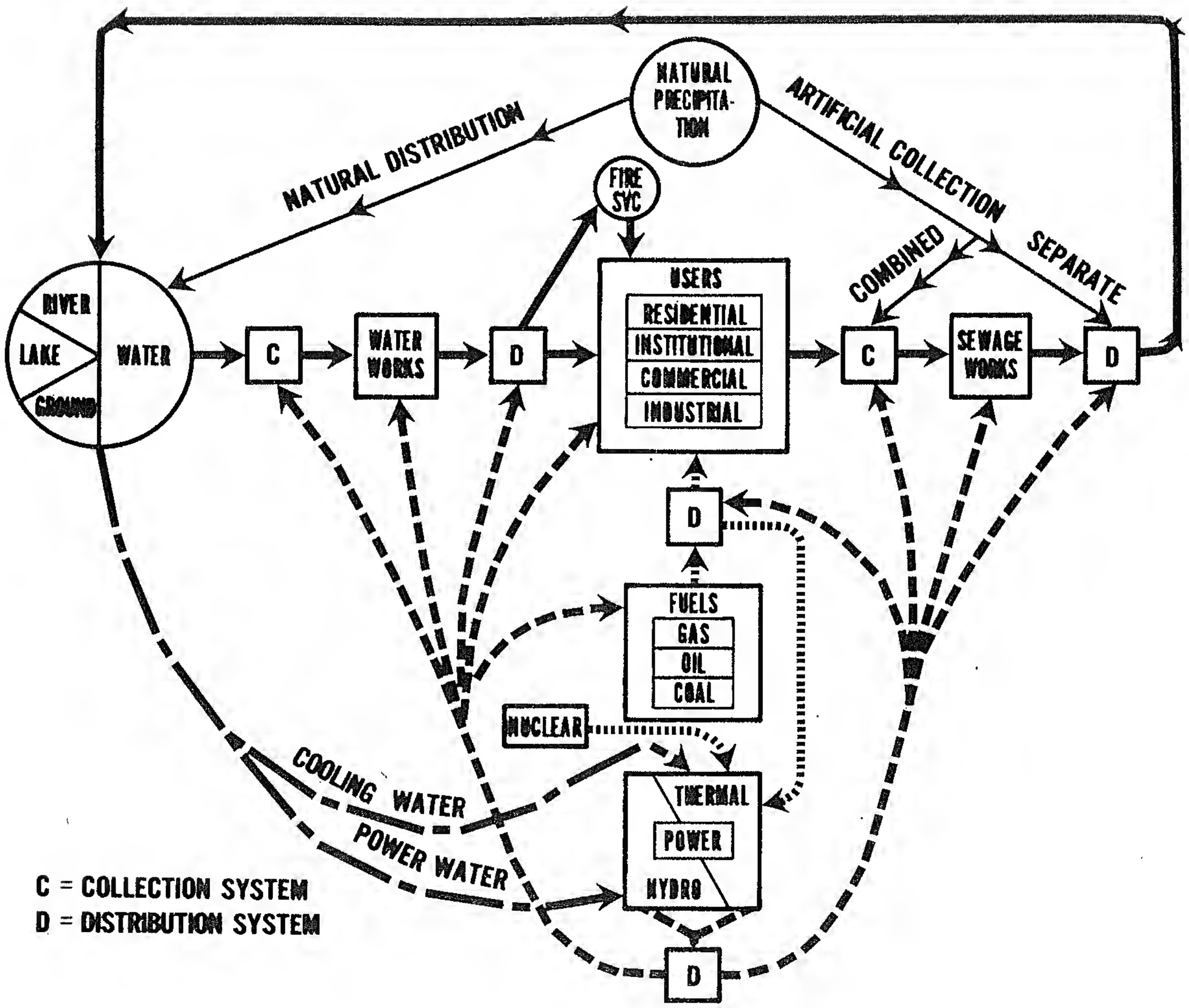
As shown in this flow chart, an urban utility system consists of inter-dependent elements, so that damage to some facilities can cause larger disruptions throughout the system. This makes it difficult to describe simply the consequences of blast damage.

Electric power is needed not only to supply light, heat, and operate motors for the main users (residential, institutional, commercial, and industrial) but also to maintain the flow of water and treatment of sewage. In general, no power should be expected above 5 psi, because of extensive damage to substations and distribution lines. In the moderate damage region, 2 to 5 psi, availability would depend on specific circumstances and early restoration of much of the service could be accomplished by isolation of damage and minor repairs. Beyond 2 psi, the distribution system would be substantially intact and power should be available.

Water treatment plants and pumping stations should remain operable at overpressures less than 5 psi, but these facilities are totally dependent on electric power unless on-site emergency generators have been provided. The most vulnerable part of the water system is the service connections and piping in buildings, which will suffer sporadic damage at 1 psi and general failure above 2 psi. If fire hydrants are served by the same system, loss of water for firefighting is likely in the moderate damage region.

Some elements of the sewage treatment system will suffer damage at low overpressures, but pumping stations will be operable up to at least 5 psi if electric power is available.

The supply of fuels is also dependent on electric power for pumping gas and oil and handling machinery for coal. Gas distribution is most vulnerable at the service connections and in buildings, much as is water piping.

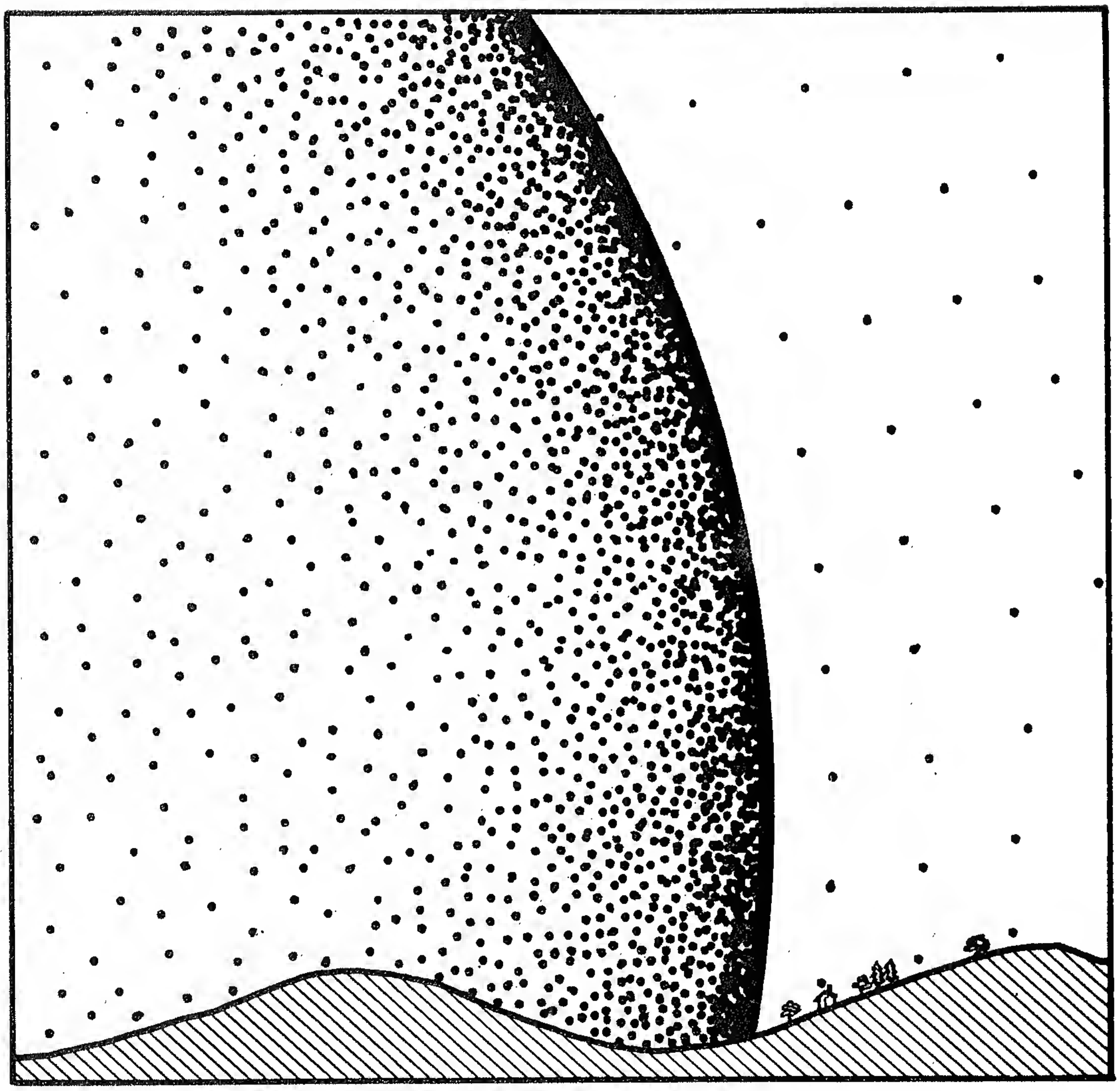

NATURAL PRECIPITA-TION
NATURAL DISTRIBUTION
ARTIFICIAL COLLECTION
FIRE SVC
COMBINED
SEPARATE
RIVER
LAKE
GROUND
WATER
C
WATER WORKS
D
USERS
RESIDENTIAL
INSTITUTIONAL
COMMERCIAL
INDUSTRIAL
C
SEWAGE WORKS
D
D
FUELS
GAS
OIL
COAL
NUCLEAR
THERMAL
POWER
HYDRO
COOLING WATER
POWER WATER
D
C = COLLECTION SYSTEM
D = DISTRIBUTION SYSTEM

PANEL 30

WHAT ABOUT HILLS?

The blast wave from a nuclear detonation is little affected by hills and other terrain features. The blast wave will exert force on the far side of a hill just as it does on the rear wall of a large building. There will be some reflection from the near side of a steep hill that could augment overpressures by perhaps 10 percent, with a corresponding reduction on the far side, but these minor changes will be of little consequence.

As the sketch shows, the blast wave from a megaton-yield explosion is so large and extends so high into the atmosphere that even prominent terrain features are small in comparison. Although hills and buildings can shield people against other weapons effects, particularly for surface bursts, little reduction in blast damage to structures may be expected. However, considerable protection from the blast wind and missiles carried by it may be achieved for vehicles and people by placing them in trenches and excavations or behind steep earthmounds (revetments).

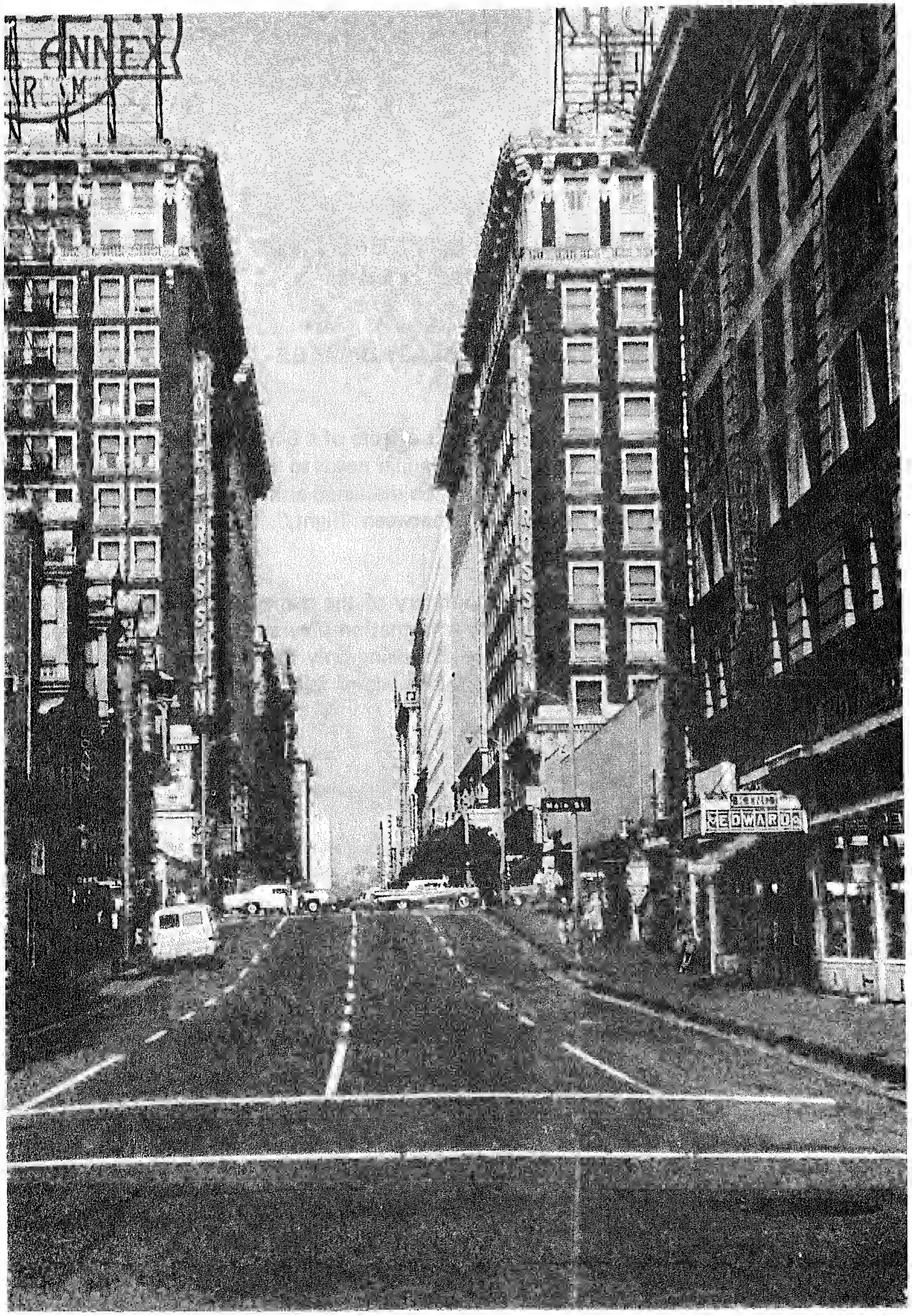


PANEL 31

BUILT-UP AREAS

The question is often raised as to whether the energy in the blast wave is not used up in the process of knocking down buildings and spreading debris. Obviously, energy is consumed and work done in the demolition process but the energy available in the blast wave is so vast that the crushing of puny man-made structures is "noticed" even less than terrain features. A locality cannot expect, then, that the blast arriving after many miles of intervening damage will be significantly diminished compared to travel over an open, featureless area.

There will be, however, considerable "self-shielding" of structures in major downtown areas. Taller buildings will reduce the effect on smaller buildings and on each other. A building in the middle of a block in the midst of other built-up city blocks will not experience the same overpressure—and, particularly, dynamic pressure—that it would standing by itself on a featureless plain. Calculations of possible effects suggest that in areas where building heights are double or more the street widths, the incident overpressure in the 10 to 20 psi region could be reduced to 75 percent of the unimpeded overpressure. That is, the damage in such areas would be more nearly like that expected at overpressures of 7 to 15 psi. This would not apply to the exposed upper floors of the taller buildings. Beyond the downtown area, the impulse in the blast wave will have been restored within a distance equal to about 5 times the average building height in the downtown area. At lower overpressures and where streets are wider than the building heights, little alteration in the blast wave can be expected.



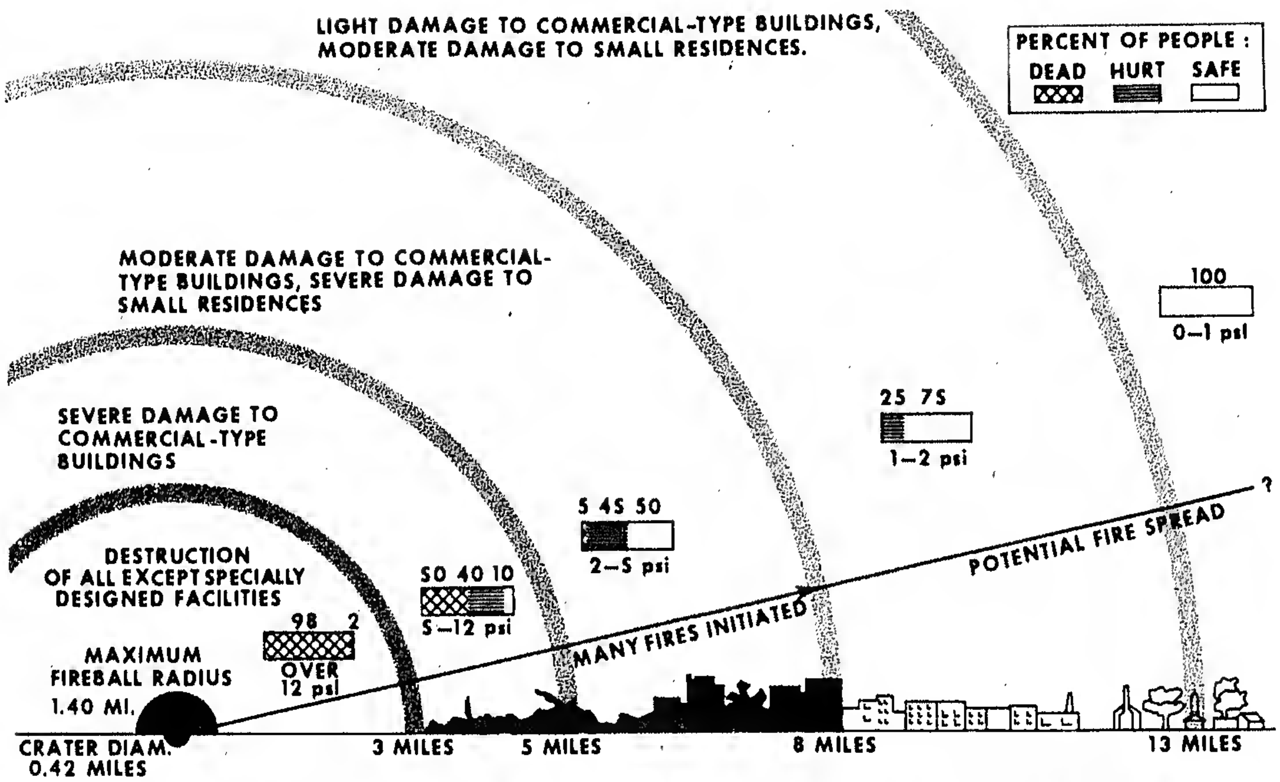
PANEL 32

A SUMMARY OF BLAST DAMAGE

Earlier, we showed this sketch of the direct effects of a 5-MT surface burst. The next few panels will summarize what the emergency planner needs to know about blast and shock effects. The same damage bands shown here will be discussed although one should recognize that there will never be a sharp dividing line between "light," "moderate," and "severe" damage.

The summary will progress from the boundary of the damaged area inward. In each damage ring, all of the damage and casualty information previously given will be brought together and related. Remember that we are discussing only blast damage in this chapter. The additional damage caused by fire and the hazards of fallout will be covered in subsequent chapters.

DIRECT EFFECTS OF 5 MT. BLAST
(SURFACE BURST)

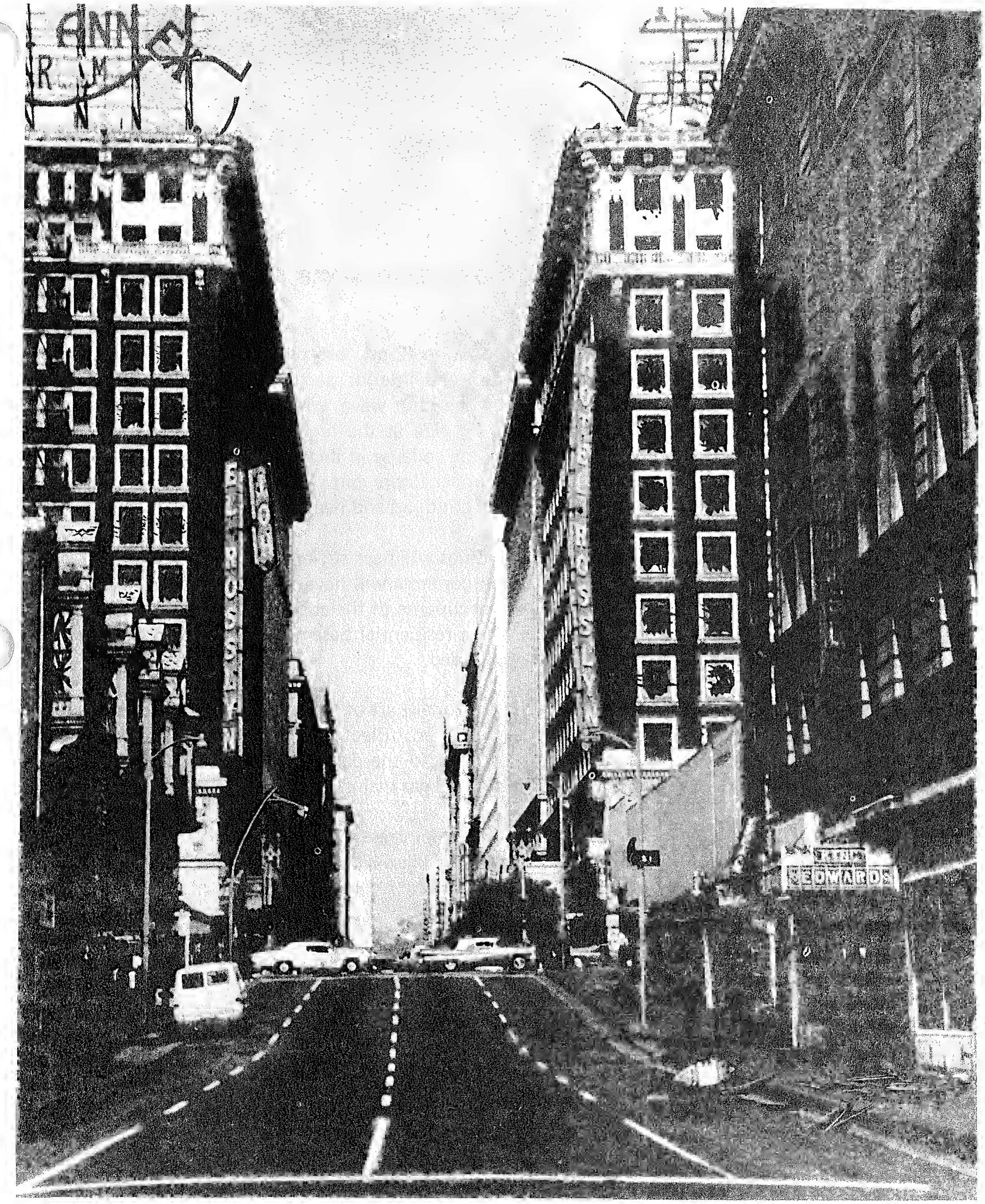


IF BURST IS ELEVATED TO ALTITUDE MAXIMIZING THE REACH OF BLAST DAMAGE, MODERATE DAMAGE FROM BLAST AND INITIAL FIRES ON A CLEAR DAY ARE EXTENDED FROM 8 MILES TO 13 MILES.

AREA OF LIGHT DAMAGE

From 13 miles in to 8 miles from a 5-MT surface detonation (1 to 2 psi), large structures would suffer broken windows and doors, and damage to light interior partitions. Most one- and two-family dwellings could be occupied but broken studs, rafters, plaster and damaged roofs would be commonplace. Some tree limbs would be down, causing minor damage to overhead wires. Gas and water service connections and interior piping would be wracked and, in many instances, broken. Street debris would be minor and limited to light signs and building ornamentation dislodged by the 35 to 70 miles per hour wind gust. Light corrugated metal siding on industrial buildings would be disrupted.

People in basements should be uninjured. Aboveground, many injuries from flying glass, other missiles, and impact against walls would occur, but most injuries would be minor cuts and abrasions. Almost everyone should survive and the simplest precautions could reduce injuries to a low level.



PANEL 34

THE AREA OF MODERATE DAMAGE

From 8 miles in to 5 miles from the detonation (2 psi to 5 psi), most large buildings would have lost their windows, window frames and interior partitions. Those with light exterior walls will have been swept through by the blast wave, with most of the walls and contents of the upper floors ejected out the far side at the higher overpressures. Load-bearing masonry buildings will have suffered some collapse in this area. There will be many injuries and some deaths among people on the upper floors, but people in basements should survive relatively uninjured except in some brick buildings and near basement entrances.

Most one- and two-family residential buildings will have suffered damage ranging from severe damage to collapse. Building debris and contents will have been blown over a large area in an outward direction. Up to half the occupants of the aboveground parts will have been killed and the remainder injured. People in residential basements will survive for the most part, although the first floor may have collapsed.

Trees and utility poles will be down over the inner part of the area. Service connections to residences and industrial buildings will be disrupted. Electric power may be available in the outer part but water pressure will be lost due to the damage to service connections. Some sporadic failures will occur in buried water and gas mains.

Debris will be substantial in cross streets but radial streets should be mostly clear except in narrow downtown streets. Tree and pole damage will occasionally block vehicular traffic on otherwise traversable streets. Pedestrian movement should be feasible throughout the area.

PANEL 35

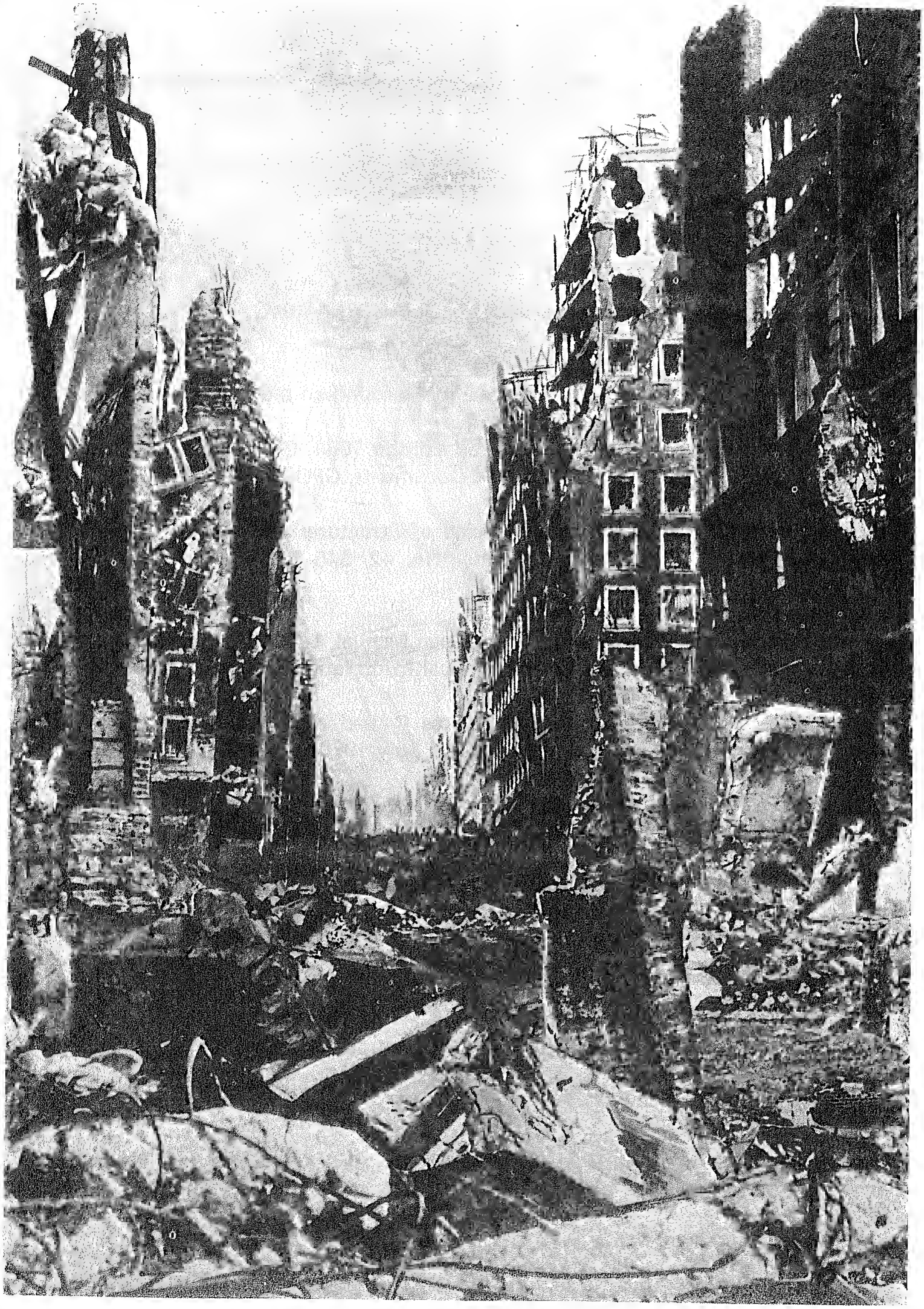
AREA OF SEVERE DAMAGE

From 5 miles in to 3 miles from the detonation (5 psi to 12 psi), the damage to structures becomes increasingly severe. Small wood-frame and brick residences have been destroyed and distributed as debris over hundreds of feet. Load-bearing masonry-walled buildings have collapsed over most of the area, with the exception of monumental buildings. Framed buildings with relatively weak walls will have been gutted throughout the area and, in the inner region, the framing will have collapsed away from the blast. Of the people aboveground, there will be many survivors, particularly between 4 and 5 miles, but few uninjured survivors. People in good basement shelter will survive with few injured in the outer part of the area, with casualties increasing toward the 3 mile circle. There will be few survivors inside of 4 miles in basements with flat-plate floors overhead and in load-bearing wall masonry buildings of the ordinary type.

Traffic into this area would be greatly hampered or impossible without debris clearance. The debris in areas of lightly-constructed buildings would probably not block radial streets severely, but large and small chunks of masonry and construction steel would make clearance in densely built-up areas a major undertaking. The feasibility of pedestrian movement would be variable throughout the area, with radial streets most likely accessible.

There would be no electricity or water pressure in this area and increasing numbers of breaks in gas and sewer mains. Radio antennas and telephone lines would be damaged such as to make communication unlikely. Automobiles would be inoperable and other vehicles would be damaged or trapped in debris except in open areas.

Closer in toward the detonation, destruction would rapidly become complete, with survivors only in the strongest underground facilities.



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SUGGESTED ADDITIONAL READING

The following sources provide additional background on the material in this chapter:

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